Masterarbeit
(master's thesis)

Aus dem Prüfungsfach:
(examination subject)

Flugbetrieb
(Flight Operations)

Analysis of the influence of the Air Traffic Management initiatives SESAR and NextGen on Airline Operations Control Centers' workflows

Betreuer:
(supervisors)

Prof. Dr.-Ing. Gerhard Hüttig (TU Berlin)
Dipl.-Ing. Ferdinand Behrend (TU Berlin)
Dipl.-Ing. (FH) Nico Zimmer (Jeppesen GmbH)

vorgelegt an der:
(submitted at)

Technischen Universität Berlin,
Fachgebiet Flugführung und Luftverkehr
(Berlin Institute of Technology, Flight Guidance and Air Transport)

von:
(by)

J. Martin Freiherr von Castell
B.Sc. Transport Systems

Tegeler Weg 25
10589 Berlin
Germany

Matrikelnummer:
(registration N^{o})

321075

Abgabetermin:
(due date, DD.MM.YYYY)

13.02.2014

This page is left blank intentionally.

ACKNOWLEDGEMENT

This research was sponsored by the Market and Solutions Research Department of Jeppesen GmbH in Neu-Isenburg, Germany.

About Jeppesen

Jeppesen is an American company founded in 1934 by Captain Elrey B Jeppesen with its headquarters in Denver, Colorado and its second largest registered office in Neu-Isenburg, Germany. Jeppesen supports people to safely and efficiently reach their destinations in the air, on the water and by land transportation. It is the world leading provider of information and optimization solutions to improve efficiency of airlines and private pilots, ship operators, sailors and rail companies. In addition, Jeppesen offers international trip planning services, navigation data, electronic and paper charts, flight and mission planning tools and more. The company is a wholly-owned subsidiary of The Boeing Company (TBC).

In the following, I would like to use the possibility to acknowledge the people who supported me in writing this thesis.

First of all, I would like to thank both Mr Prof. Dr.-Ing. Gerhard Hüttig and Mr Dipl.-Ing. Ferdinand Behrend (Berlin Institute of Technology, Flight Guidance and Air Transport) who encouraged and fostered me in writing this thesis. As they are not only my teachers but also fellow colleagues, I am grateful to say that they always supported me, both in terms of my studies and my daily work. Moreover, I thank all other colleagues who inspired and supported me during the last four years of our collaboration, especially Mr cand. Ing. Kalevi Anders, Mr Prof. Dr. iur. Elmar Giemulla, Mr Dipl.-Ing. Bastian Göbel, Ms Sylvia Halacz, Ms RA Juliane Holtz, Mr Dr.-Ing. Oliver Lehmann, Mr Robert Marx, Mr Dr.-Ing. Holger Schulz (airsight GmbH) and Ms Dipl.-Ing. Lisa Thiel.

Furthermore, I would like to express my gratitude to the Jeppesen research team who gave me the opportunity to join them. Although I wrote this thesis remotely and was not at their Neu-Isenburg office very often, I found the few times I spent with them very motivating and inspiring. A special thanks goes to Mr Dipl.-Ing. (FH) Nico Zimmer and Mr Dr.-Ing. Nima Barraci. I also want to thank Mr Dean Levi from Jeppesen Denver (USA) for his encouragement and advice regarding the integration of Airline Operations Control Centers (OCC) in NextGen. It was not only great working with such a committed and ambitious team, but also impressively showed me how visionary thinking, global cooperation and sustainable research may both influence global markets and improve the way people fly.

Additionally, I am deeply indebted to all my former Air Berlin colleagues who contributed to my thesis, especially in giving me the permission of visiting the Air Berlin OCC as to analyze local workflows and process structures. Without their encouraged input I would never have been able to accomplish this research. Therefore, my special thanks – in place of all the other Air Berlin employees who kindly supported me – go to Mr Ibrahim Gülcan (Air Berlin, Manager OCC), Mr Knut Ulrich (Air Berlin, Manager Production Planning) and Mr Hermann Lindner (Air Berlin, Political Affairs).

Last but not least, I would also like to sincerely thank my family and close friends for the support they provided me through my entire life and the years of my studies. As the writing of this thesis was a really complex, time-consuming undertaking and sometimes prevented me from sharing time with them, I deeply appreciate their inexhaustible love, patience, back up and encouragement.

CONTENT

LIST OF FIGURES

LIST OF TABLES

LIST OF FORMULAS

ACRONYMS

4DT	4D Trajectory
A-SMGCS	Advanced Surface Movement Guidance and Control System
A/C	Aircraft
A/G	Air(craft)-to-Ground
AAtS	Aircraft Access to SWIM
ACARS	Aircraft Communications, Addressing and Reporting System
ADS-B	Automatic Dependent Surveillance Broadcast
AIS	Aeronautical Information Services
AIXM	Aeronautical Information Exchange Model
ALRS	Alerting Service
AMM	Airport Moving Map
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
AOC	Airport Operations Center
AOCC	Airline Operations Control Center (= OCC, FOC)
AOG	Aircraft On Ground (means: A/C unserviceable)
APU	Auxiliary Power Unit
ASK	Available Seat Kilometers
ASM	Airspace Management (also: Available Seat Miles)
ATA	Actual Time of Arrival
ATC	Air Traffic Control (Service)
ATD	Actual Time of Departure
ATFM	Air Traffic Flow Management
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATS	Air Traffic Services
BRP	Break Release Point
CAGR	Compound Annual Growth Rate
CCD	Continuous Climb Departure
CDA	Continuous Descent Approach
CDL	Configuration Deviation List
CDM	Collaborative Decision Making
CG	Center of Gravity
CI	Cost Index
CIS	Commonwealth of Independent States

CNS	Communication, Navigation und Surveillance
COI	Communities of Interest
ConOps	Concept of Operations
COTS	Commercial Off-The-Shelf (products)
CPDLC	Controller Pilot Data Link Communications
CTA	Controlled Time of Arrival
DCB	Demand and Capacity Balancing
DCS	Departure Control System
DHS	U.S. Department of Homeland Security
DOC	Direct Operating Costs (also: U.S. Department of Commerce)
DOD	U.S. Department of Defense
DOO	Day Of Operations
DOT	U.S. Department of Transportation
DSS / DST	Decision Support Systems / Decision Support Tools
EC	European Council
ECAA	European Common Aviation Area
EEC	European Economic Community
EFTA	European Free Trade Association
EOBT	Estimated Off-Block Time
EP	European Parliament
ETD	Estimated Time of Departure
EU	European Union
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration
FAB	Functional Airspace Block
FANS	Future Air Navigation System
FH	Flight Hour
FIS	Flight Information Service
FL	Flight Level
FLTD	Flight Deck
FMS	Flight Management System
FOB	Fuel On Board
FOC	Flight Operations Center (= OCC, AOCC)
FY	Fiscal Year
GDP	Gross Domestic Product
GND	Ground

GNSS	Global Navigation Satellite System
HTML	HyperText Markup Language
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IP	Internet Protocol
IRM	Integrated Risk Management
ISA	ICAO Standard Atmosphere
JPDO	Joint Planning and Development Office
KPA	Key Performance Area
KPI	Key Performance Indicator
LCC	Low Cost Carrier
LoS	Level of Service
LW	Landing Weight
MCC	Maintenance Control Center (also: Multi Crew Cooperation)
MEL	Minimum Equipment List
MET	Meteorological Service(s)
METAR	Meteorological Aviation Routine Weather Report (also known as: Meteorological Terminal Air Report)
MSL	Mean Sea Level
MTOW	Maximum Take Off Weight
NAA	National Aviation Authority
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NAVAID	Navigational Aid
NextGen	Next Generation Air Transportation System
NM	Network Manager (also: Nautical Mile)
NOP	Network Operations Plan
NOTAM	Notice to Airmen
OBT	Off Block Time
OCC	Operations Control Center (= AOCC, FOC)
ODNI	U.S. Office of the Director of National Intelligence
OFP	Operational Flight Plan
OI	Operational Improvement
OSTP	White House Office of Science and Technology Policy

PANS	Pan European Network System
PAX	Passenger
PBO	Performance-Based Operations
PLF	Passenger Load Factor (=SLF)
PNT	Positioning, Navigation and Timing Services
PPP	Public-Private Partnership (also: Purchasing Power Parity)
QNH	(Q-code) Atmospheric pressure adjusted to MSL
R&D	Research and Development
RADAR	Radio Detection And Ranging
RBT	Reference Business Trajectory
RPK	Revenue Passenger Kilometers
RTCA	Radio Technical Commission for Aeronautics
RTK	Revenue Ton Kilometers
SAR	Search And Rescue
SARPs	Standards And Recommended Practices
SATCOM	Satellite Communications
SES	Single European Sky
SES I	SES I package
SES II	SES II package
SESAR	Single European Sky ATM Research (programme)
SESAR JU	SESAR Joint Undertaking (= SJU)
SJU	SESAR Joint Undertaking (= SESAR JU)
SLF	Seat Load Factor (=PLF)
SMS	Safety Management System
SOA	Service Oriented Architecture
SWIM	System Wide Information Management
SWIM-SUIT	SWIM – SUpported by Innovative Technologies
T/C	Top of Climb
T/D	Top of Descent
TAF	Terminal Area Forecast (also known as: Terminal Aerodrome Forecast)
TBO	Trajectory-Based Operations
TMA	Terminal Manoeuvring Area
TORA	Take Off Run Available
TOW	Take Off Weight
TPT	Touchdown Point
TTA	Target Time of Arrival

TW	Taxi Weight
UTC	Coordinated Universal Time
VDL	VHF Data Link
VFR	Visual Flight Rules
VHF	Very High Frequency
VMC	Visual Meteorological Conditions
WG	Working Group
WP	Work Package
Wx	Weather
XML	Extensible Markup Language
ZFW	Zero Fuel Weight

DEFINITIONS

4D-Trajectory (4DT): A 4DT represents the "centerline" of a path plus the positioning uncertainty, including waypoints. Positioning uncertainty includes lateral, longitudinal, and vertical positioning uncertainty. Some waypoints within a 4DT may be defined with controlled times of arrival (CTAs), which constrains the uncertainty for planning purposes. The required level of specificity of the 4DT will depend on the operating environment in which the flight will be flown. Associated with a 4DT is the separation zone around an aircraft and the aircraft intent information, which provides near-term information on the expected flight path.

Actual Time of Arrival (ATA): The point in time when the landing aircraft touches the runway at the Touchdown Point (TPT).

Actual Time of Departure (ATD): The point in time when the cockpit crew of the departing aircraft releases brakes on the runway and applies take off thrust at the Break Release Point (BRP).

Advanced Surface Movement Guidance and Control System (A-SMGCS): A system developed to ensure safer and more efficient aircraft ground surface movements as well as surveillance of those aircraft taxiing on heavily used airports during low visibility operations.

Aircraft Access to SWIM (AAtS): AAtS is a data-sharing network to provide aircraft flight crews with near real-time information about operations conducted in the NextGen environment. AAtS will enhance situational awareness of flight crews and facilitate collaborative decision making.

Airline Operations Control Center (AOCC, OCC): An OCC is an organizational unit of an airline which is in charge of managing day-to-day operations in order to execute complex flight schedules, which are created weeks or even months in advance whilst ensuring both efficient and safe operations. It is regarded as an airline's nerve center since all tactical decisions concerning an airline's air traffic operations, e.g. how to address sudden disruptions, are made in the OCC. Therefore, an OCC strongly and continuously influences an airlines' economics as the outcomes of a decision can mostly be measured according to costs caused and/or profits drawn.

Air Traffic Advisory Service (ATAS): A service provided within advisory airspace to ensure separation, in so far as practical, between aircraft which are operating on IFR flight plans. The Air Traffic Advisory Service must not deliver clearances but only advisory information.

Air Traffic Control (ATC): A service provided for the purpose of preventing collisions between airborne aircraft, and – on the maneuvering area – between aircraft and obstructions. It furthermore serves to expedite and maintain an orderly flow of air traffic. ATC is the only ATS entity which is allowed to give clearances.

Air Traffic Flow Management (ATFM): ATFM is a main ATM function established with the objective of contributing to a safe, orderly and expeditious flow of air traffic by ensuring that ATC capacity is utilized to the maximum extent possible and the traffic volume is compatible with the capacities declared by the appropriate ATS authority.

Air Traffic Management (ATM): ATM encompasses the dynamic, integrated management of air traffic and airspace including Air Traffic Services (ATS), Airspace Management (ASM) and Air Traffic Flow Management (ATFM) – safely, economically and efficiently – through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions.

Air Traffic Services (ATS): ATS represent a main function of the ATM. The generic term ATS is used to describe the four operational services Air Traffic Control Service (ATC), Flight Information Service (FIS), Alerting Service (ALRS) and Air Traffic Advisory Service (ATAS) which are provided by an Air Navigation Service Provider (ANSP).

Airspace Management (ASM): The ASM is a main ATM function aiming at organizing and optimizing the airspace and its airways. ASM's primary objective is to maximize the utilization of available airspace by dynamic time-sharing and, at times, the segregation of airspace among various categories of

users based on short-term needs. In future systems, ASM will also have a strategic function associated with infrastructure planning.

Alerting Service (ALRS): A service provided to notify appropriate organizations regarding aircraft in need of search and rescue (SAR) aid, and assist such organizations as required.

ATC Flight Plan: An ATC flight plan is a document which provides specified information to air traffic service units relative to an intended flight or portion of a flight of an aircraft, according to the provisions given in ICAO Annex 2 (Rules of the Air).

Automatic Dependent Surveillance-Broadcast (ADS-B): ADS-B is a surveillance technique that relies on aircraft or airport vehicles broadcasting their identity, position and other information derived from on board systems (GNSS etc.). This signal can be captured for surveillance purposes on the ground (ADS-B Out) or on board other aircraft (ADS-B In). The latter will enable situational awareness in airborne traffic, spacing, separation and self-separation applications. ADS-B is automatic because no external stimulus is required; it is dependent because it relies on on-board systems to provide surveillance information to other parties. Finally, the data is broadcast, the originating source has no knowledge of who receives the data and there is no interrogation or two-way contract. ADS-B has been developed to replace the increasingly insufficient RADAR technology.

Available Seat Kilometer (ASK): A unit of transportation measurement, calculated by multiplying the number of available passenger seats and the distance flown, usually either related to a single aircraft operation or an airline's entire flight plan. Thus, one ASK means that an airline is capable of transporting one paying passenger over a distance of one kilometer. This does not mean that this transportation really happens, as the amount of ASK is always equal or greater than the amount of Passenger Revenue Kilometers (PRK).

Business Trajectory (4DT): The Business Trajectory is a trajectory which expresses the business intentions of civil airspace users (respectively mainlines, regional, business or general aviation). It includes both surface and airborne segments and is built from – and updated with – the most timely and accurate data, including turn-around elements. Once agreed by all stakeholders, the Business Trajectory becomes the Reference Business Trajectory.

Centralized Organization: A management structure where decision making is done at higher consolidated levels by those with a broader perspective that includes having amassed considerable knowledge and information about what needs to be done. In a centralized organization, decisions made by higher management are typically communicated to lower organizational tiers who are then expected to accept and move forward in a way consistent with those decisions.

Collaborative Decision Making (CDM): CDM is already used at a number of European airports. In SESAR and NextGen this method of decision making will not be confined only to airports but will be further developed and spread throughout the ATM network. It needs to cover the sharing of information related to the progress of flights (on the ground and in the air) and the actions taken on this information. It is not a separate part of the ATM network, but a method of working which is applicable to most decision making aspects of the ATM operational concept.

Configuration Deviation List (CDL): A Configuration Deviation List (CDL) is a list established by the organization responsible for the type design with the approval of the state of design which identifies any external parts of an aircraft type which may be missing at the commencement of a flight, and which contains, where necessary, any information on associated operating limitations and performance correction, according to ICAO Annex 6, Part I. The CDL is usually prepared by the aircraft manufacturer.

Continuous Climb Departure (CCD): An optimized departure from an airport to a defined point or level without intermediate level offs.

Continuous Descend Approach (CDA): An optimized decent and approach to an airport from a defined point without intermediate level offs.

Controlled Time of Arrival (CTA): The assignment and acceptance of an entry / use time for a specific ATM resource. Examples include point-in-space metering, time to be at a runway, or taxi waypoints.

Controller Pilot Data Link Communications (CPDLC): CPDLC is a two-way data-link system by which controllers can transmit messages to the pilot without the use of voice communications. The message is displayed on a flight deck visual display. Communication procedures are detailed in ICAO Annex 10 Volume III Part 1 Chapter 3. The CPDLC message set is contained in ICAO Doc 4444: PANS-ATM, Annex 5.

Cost Index (CI): The CI is the ratio of the time-related cost of an airplane operation and the cost of fuel. The value of the CI reflects the relative effects of fuel cost on overall trip cost as compared to time-related Direct Operating Costs (DOC).

Departure Control System (DCS): A DCS is used by airlines as to manage the information required for airport check-in and printing boarding card, baggage acceptance, boarding, load control and aircraft checks.

Direct Operating Costs (DOC): DOC represent the total of flight operations costs (flight crew salaries and expenses, aircraft fuel and oils, aircraft insurances, aircraft rentals, flight crew training – where not amortized, and other flight expenses), maintenance and overhaul costs, depreciation and amortization (aircraft, required ground equipment and associated property). Operators and analysts will further subdivide DOCs into fixed and variable, with flight crew salaries, depreciation, aircraft rentals, insurances, and maintenance burden determined as fixed, while fuels and oils, flight crew and other expenses, as well as airframe and engine maintenance are considered variable.

Estimated Time of Departure (ETD): The estimated time at which the aircraft will commence movement associated with departure.

EUROCONTROL: EUROCONTROL is an intergovernmental organization with 38 Member States. EUROCONTROL's mission is to harmonize and integrate air navigation services in Europe, aiming at the creation of a uniform air traffic management (ATM) system for civil and military users, in order to achieve the safe, secure, orderly, expeditious and economic flow of traffic throughout Europe, while minimizing adverse environmental impact. It also counts the European Community as a member and is governed by an international convention.

European Aviation Safety Agency (EASA): The European Aviation Safety Agency (EASA) is an agency of the European Union (EU) established in 2002 by Regulation (EC) No. 1592/2002 in order to ensure a high and uniform level of safety in civil aviation by the implementation of common safety rules and measures. EASA has taken over the responsibilities of the former Joint Aviation Authorities (JAA) system which ceased on 30 June 2009. However, it is not a successor agency in legal terms since it functions directly under EU statute. The main difference between EASA and the JAA is that EASA is Regulatory Authority which uses National Aviation Authorities (NAA) to implement its Regulations whereas the JAA relied upon the participating NAAs to apply its harmonized codes without having any force of law at source. Since it is impossible to create a new Regulatory System out of nothing, EASA has had to accept large parts of the JAA system as its own whilst developing the new harmonized system required under EU statute.

European Union (EU): The European Union (EU) is an economic and political union of 28 European countries. The EU was established on 1 November 1993 by the Treaty on European Union (also known as Maastricht Treaty). The EU today has a surface area of approximately 4,381,000 km², 507,890,000 inhabitants and 24 official languages. The EU Member States are as follows: Austria (1995), Belgium (1994), Bulgaria (2007), Croatia (2013), Cyprus (2004), the Czech Republic (2004), Denmark (1994), Estonia (2004), Finland (1995), France (1994), Germany (1994), Greece (1994), Hungary (2004), Ireland (1994), Italy (1994), Latvia (2004), Lithuania (2004), Luxembourg (1994), Malta (2004), the Netherlands (1994), Poland (2004), Portugal (1994), Romania (2007), Slovakia (2004), Slovenia (2004), Spain (1994), Sweden (1995) and the United Kingdom (1994). The years given in parentheses represent the year of joining the EU.

Federal Aviation Administration (FAA): The Federal Aviation Administration (FAA) is the agency of the United States Department of Transportation responsible for the regulation and oversight of civil

aviation within the USA, as well as operation and development of the National Airspace System (NAS). Its primary mission is to ensure safety of civil aviation. Along with the European Aviation Safety Agency (EASA), the FAA is one of the two main agencies responsible for the certification of aircraft globally.

Flight Information Service (FIS): FIS is provided in order to advise and inform airspace users about safety-related issues and maintain an orderly and efficient flow of traffic. In contrast to the ATC, the FIS must not give clearances.

Flight Management System (FMS): A FMS is an on-board multi-purpose navigation, performance, and aircraft operations computer designed to provide virtual data and operational harmony between closed and open elements associated with a flight from pre-engine start and take-off, to landing and engine shut-down.

Functional Airspace Block (FAB): One of the main objectives of the European Union's SES initiative is to restructure the entire European airspace by combining different airspaces into so-called FABs solely according to operation reasons, regardless of national borders.

Gross Domestic Product (GDP): The term Gross Domestic Product (GDP) indicates the value of all final goods and services produced in a country in one year. GDP can be measured by adding up all of an economy's incomes – wages, interest, profits, and rents – or expenditures – consumption, investment, government purchases, and net exports (exports minus imports). Both results should be the same because one person's expenditure is always another person's income, so the sum of all incomes must equal the sum of all expenditures.

Instrument Flight Rules (IFR): Unlike Visual Flight Rules (VFR), Instrument Flight Rules (IFR) are rules which allow properly equipped aircraft to be flown under Instrument Meteorological Conditions (IMC). IFR are detailed in ICAO Annex 2: Rules of the Air.

Instrument Meteorological Conditions (IMC): Instrument Meteorological Conditions (IMC) are meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling, less than the minima specified for Visual Meteorological Conditions (VMC). IMC conditions exist when the outside view from an aircraft is restricted in such a way that aircraft control and navigation can only be carried out using special flight instruments. IMC are detailed in ICAO Annex 2: Rules of the Air.

International Civil Aviation Organization (ICAO): The constitution of the International Civil Aviation Organization (ICAO) is the Convention on International Civil Aviation, drawn up at a conference in Chicago in 1944 to which each ICAO contracting state is a party. This convention is also known as the Chicago Convention. In October 1947, ICAO became a specialized agency of the newly-established United Nations (UN). The Chicago Convention set down the purpose of ICAO, as it is to agree on certain principles and arrangements to the effect that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically. ICAO Standards and Recommended Practices (SARPS) for each area of ICAO responsibility are contained in 18 Annexes. Contracting states (currently 180) are required to give notification of differences in standards, and required to report differences from Recommended Practices in Annexes. It should be noted that ICAO Standards do not preclude the development of national standards which may be more stringent than those contained in an Annex.

Joint Planning and Development Office (JPDO): The United States Congress established the JPDO in 2003 to plan and coordinate the development of NextGen. The JPDO is a multi-agency public / private initiative and includes the following U.S. departments: United States Department of Transportation, United States Department of Defense, Department of Commerce, Department of Homeland Security, Federal Aviation Administration, National Aeronautics and Space Administration, and White House Office of Science and Technology Policy.

Key Performance Area (KPA): KPAs represent a group of related key performance indicators (KPIs).

Key Performance Indicator (KPI): A KPI is a type of quantifiable performance measurement which is used to evaluate the success of a particular activity or process with pre-defined goals.

Minimum Equipment List (MEL): The operator shall include in the operations manual a minimum equipment list (MEL), approved by the state of the operator which will enable the pilot-in-command to determine whether a flight may be commenced or continued from any intermediate stop should any instrument, equipment or systems become inoperative. Where the state of the operator is not the state of registry, the state of the operator shall ensure that the MEL does not affect the aircraft's compliance with the airworthiness requirements applicable in the state of registry, according to ICAO Annex 6, Part I. An operator may not operate an aircraft which does not comply with the approved MEL, except with the explicit permission of the appropriate regulatory authority.

Mission Trajectory (4DT): The Mission Trajectory is a trajectory which expresses the mission intentions of the military airspace user. It includes both surface and airborne segments and is built from, and updated with the most timely and accurate data, including turn-around elements. Mission Trajectory may additionally include specific airspace reservations when such airspace structure is needed. Once agreed upon by all stakeholders, the Mission Trajectory becomes the Reference Mission Trajectory.

National Airspace System (NAS): The NAS is a complex network of airports, airways, and ATC facilities that exists to support the commercial, private and military use of aircraft in the USA. It represents the entire American ATM network.

Net-centric (also: network-centric): A net-centric (also: network-centric) infrastructural system consists of a steadily altering, complex association of people, devices, information, sub-systems and services interconnected by a harmonized, common communications network to gain optimal benefit of resources and better synchronization of events.

Network Operations Plan (NOP): The Network Operations Plan (NOP) is a set of information and actions derived and reached collaboratively both relevant to, and serving as a reference for, the management of the ATM network in different timeframes for all ATM stakeholders, which includes, but is not limited to, targets, objectives, how to achieve them, anticipated impact.

Next Generation Air Transportation System (NextGen): The US American initiative aimed at the modernization of the American ATM system is called NextGen. The Joint Programme Development Office's (JPDO) Integrated Work Plan (IWP) presents the research, development, and implementation efforts of the US government and its industry partners to achieve the Next Generation Air Transportation System (NextGen) vision. This initiative is being coordinated with the SESAR initiative in Europe in order to assure alignment where necessary and joint inputs to ICAO.

Notice to Airmen (NOTAM): A notice containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations, according to ICAO Annex 11. NOTAMs are issued by national authorities.

Operational Flight Plan (OFP): The aircraft operator's plan for the safe and efficient conduct of a given flight based on considerations of aircraft performance, other operating limitations and relevant expected conditions on the route to be followed and at the aerodromes concerned, according to ICAO Annex 6, Part I.

Passenger Load Factor (PLF): *See: Seat Load Factor (SLF)*

Performance-Based Operations (PBO): Use of a performance capability definition versus an "equipment" basis to define the regulatory and procedural requirements to perform a given operation in a given airspace.

Public-Private Partnership (PPP): A public–private partnership (PPP) is a government service or private business venture which is funded and operated through a partnership of government and one or more private sector companies. These partnerships are sometimes also referred to as P3 or P^3.

QNH: Aircraft pressure altimeters indicate the elevation of the aircraft above a defined datum. The datum selected depends on the barometric pressure set on the altimeter sub-scale. Sound altimeter setting procedures are an essential tool in ensuring safe separation from the ground and from other aircraft. Three references for barometric pressure are in common usage: QNH, QFE and Standard

Pressure (= 1013,25 millibar, also referred to as QNE). With QNH set, an aircraft altimeter indicates height above Mean Sea Level (MSL). The QNH may be the pressure observed at the airfield, or the lowest pressure observed throughout a specified geographical area.

Reference Business Trajectory (RBT): The Business Trajectory which the civil airspace user agrees to fly and the ANSP and airports agree to facilitate (subject to separation provision).

Reference Mission Trajectory (RMT): The Mission Trajectory which the military airspace user agrees to fly and the ANSP and airports agree to facilitate (subject to separation provision).

Revenue Passenger Kilometer (RPK): A unit of transportation measurement, calculated by multiplying the number of revenue-generating passengers transported by an airline and the distance flown, usually either related to a single aircraft operation or an airline's entire flight plan. Thus, one RPK means that an airline transported one paying passenger over a distance of one kilometer.

Revenue Tonne Kilometer (RTK): A unit of transportation measurement, calculated by multiplying the number of revenue-generating tonne of cargo transported by an airline and the distance flown, usually either related to a single aircraft operation or an airline's entire flight plan. Thus, one RTK means that an airline transported one tonne of cargo over a distance of one kilometer.

Safety Management System (SMS): A process that provides a systematic method for managing safety. The four components of an SMS are policy, architecture, assurance and safety promotion.

Seat Load Factor (SLF): A unit of transportation measurement, calculated by dividing the number of Revenue Passenger Kilometers (RPK) and the number of Available Seat Kilometers (ASK). SLF is usually either related to a single aircraft operation or an airline's entire flight plan. Thus, the SLF is a ratio which indicates how efficiently an airline can use its existing seat capacity.

Service Oriented Architecture (SOA): A paradigm for organizing and utilizing distributed capabilities that may be under the control of different ownership domains. It provides a uniform means to offer, discover, interact with, and use capabilities to produce desired effects consistent with measurable preconditions and expectations.

Single European Sky (SES): Legal framework established by the European Union in 2004 in order to increase airspace capacity in the European airspace by developing and implementing more efficient and safer ATM structures and procedures by 2020. One important objective is to restructure the current European airspace by abolishing national airspace borders and creating so called Functional Airspace Blocks (FAB).

Single European Sky ATM Research programme (SESAR): SESAR aims at developing the new generation European air traffic management (ATM) system capable of ensuring the safety and efficiency of European air transport over the next 30 years**.** This initiative is being coordinated with the NextGen initiative in the United States of America in order to assure alignment where necessary and joint inputs to ICAO.

System Wide Information Management (SWIM): The System Wide Information Management (SWIM) concept is essential for the future European and US American Air Traffic Management (ATM) systems. In essence, SWIM envisages an 'intranet of the air' where the ATM information held by different stakeholders in the system are shared over a common platform. Each stakeholder (including aircraft, airports or national airspace managers, for example) has access to the information they need to carry out their role in the ATM system. Both the European (SESAR) and US American ATM initiatives (NextGen) foster SWIM interoperability.

Target Time of Arrival (TTA): An ATM computed arrival time. It is not a constraint but a progressively refined planning time that is used to coordinate between arrival and departure management applications.

Trajectory-Based Operations (TBO): The use of 4DTs as the basis for planning and executing all flight operations supported by the air navigation service provider.

Visual Flight Rules (VFR): Visual Flight Rules (VFR) are the rules that govern the operation of aircraft in Visual Meteorological Conditions (VMC). Because of the limited communication and/or navigation equipment, VFR flights may be subject to limitations if permitted in controlled airspace. Minimum requirements for VFR flights are detailed in EU-OPS 1 and JAR-OPS 3.

Visual Meteorological Conditions (VMC): Visual Meteorological Conditions (VMC) are the meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling equal to or better than specified minima. They define conditions in which flight is possible solely by visual reference. VMC are detailed in ICAO Annex 2.

Workflow: The automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action according to a set of procedural rules.

ABSTRACT

Anmerkung (Remark for German-speaking readers): Eine deutsche Version dieses Abstracts findet sich in Annex 10 – German Abstract (Zusammenfassung).

Introducing the Topic

During the next two decades, the way Air Traffic Management (ATM) is conducted will have to alter significantly due to globally changing framework conditions. This is mainly because of the steadily rising demand for air transportation at constant, limited airspace volumes, which – in direct return – makes increases in both capacity and safety become inevitable. Moreover, political decision makers as well as ATM stakeholders increasingly foster aspects like environmental protection and sustainability.

Both the European Union (EU) and the United States of America (USA) responded to this situation politically by launching the ATM initiatives SESAR (Single European Sky ATM Research) and NextGen (Next Generation Air Transport System) respectively. These contain binding provisions and manifold requirements which will influence all ATM stakeholders conducting flights within European and U.S. American airspaces in the future; this also encompasses airlines and their Operations Control Centers which represent an airline's operational control room. The OCCs' main functions are to monitor and control all relevant operating procedures and to handle sudden and/or unforeseen disruptions (e.g. inoperable aircraft, severe weather conditions). Thereby, not only the safety, but also the cost and time efficiency of flight operations has to be accounted for. As to be able to perform their tasks, today's OCCs mainly interact with the ATM stakeholders *Air Traffic Control* (ATC) and *cockpit crews*.

Objective and Scientific Approach of this Master's Thesis

This master's thesis aims to analyze how the above mentioned ATM initiatives SESAR and NextGen will influence both the structure and workflows of today's OCCs as well as existing OCC-cockpit crew operating procedures.

Therefore, the need for SESAR and NextGen is clarified (Chapter 1) and both projects' documentation as well as adherent secondary literature and scientific papers are examined and compared to each other (Chapters 3 to 5).[1] Subsequently, the setting, workflows and structures of today's OCCs as well as their integration into airline planning processes and the interaction of OCC-cockpit crew workflows are specified (Chapter 6). Based on the provisions specified in SESAR and NextGen, schemes for future OCC integration into long- and short-term airline planning processes as well as pre- and in-flight OCC-cockpit crew workflow interaction are derived and analyzed by applying them to three self-defined scenarios. Adapted from that, a gap analysis is performed as to identify missing provisions and conceptual inadequacies (Chapter 7). Finally, a short conclusion of the results of this thesis and an overview of thematically-related issues which should be subject of further scientific research are provided (Chapter 8). This, e.g., encompasses the interoperability of SESAR and NextGen when it comes to transatlantic flight operations.

Results

In today's roadmap of the ATM initiatives, the future roll of OCCs is not specified sufficiently, neither by SESAR nor NextGen. Both initiatives' project documentations lack information when it comes to the future role, integration and operation of OCCs. It remains unclear which part OCCs will take in the future. Taking the SESAR (2020) and NextGen (2025) implementation timeframes into consideration, it has to be asserted that a timely, cost- and time-

1 Remark: Chapter 2 clarifies the scientific approach of this master's thesis and gives a general overview of its content, scope and structure.

efficient implementation of necessary adaptions to both strategic and operational OCC processes is highly questionable due to missing provisions and specifications.

In July 2012, the responsible Joint Planning and Development Office (JPDO) project management team has – in contrast to their European colleagues from SESAR Joint Undertaking (SJU) – published a report[2] validating the concept of OCC integration as specified in the NextGen ConOps and adherent documents. This validation especially focuses on the intended implementation of the NextGen (and SESAR) key features *Collaborative Decision Making (CDM)*, *System Wide Information Management (SWIM)* and *Trajectory-Based Operations (TBO)* and lists several findings concerning the general OCC integration into NextGen; those are, amongst others, a missing overall OCC focus because of a strong conceptual emphasis on ATC-cockpit crew cooperation, inadequate specification of SWIM protocols as well as missing rules for both data sharing between different CDM stakeholders by means of SWIM and ATM resource allocation. Moreover, the JPDO criticizes that NextGen does not sufficiently consider strategic aspects when it comes to the OCC planning horizon; hence, as it will be one of the OCCs' main tasks to initiate and negotiate 4DTs within a CDM environment weeks or even months before a given flight is conducted, it is essential that OCCs extend their operational range on long-term strategic planning and do not only cover short-term tactical planning and operational control, as they do nowadays. According to JPDO recommendations, these findings have to be resolved by means of conceptual modifications as to ensure the overall operational efficiency of NextGen.

As seen from the SESAR perspective and considering the fact that SESAR shall be fully established five years earlier than NextGen, it has to be stated that there is neither a validation report nor a detailed concept for OCC integration published or even available so far. Asked for the reasons for this, two leading SJU project managers[3] did not reply, even upon repeated written inquiry. The shortage of information on OCC integration into SESAR is also criticized by executive officers[4] of two well-respected German airlines, Air Berlin and Lufthansa.

However, based on the specifications of the SESAR and NextGen key features as defined in the respective ConOps and ATM Masterplans and by assuming that associated provisions will be implemented accordingly, it was possible to derive a concrete, reasonable scheme describing how future OCC workflows as well as OCC-cockpit crew interactions will be influenced by the SESAR and NextGen key features. This scheme was then compared to the current situation by means of a gap analysis, identifying the following gaps:

- The creation and transmission of ATC flight plans as well as respective OCC-cockpit crew workflows will become obsolete as ATC flight plans will be substituted by a single, system-wide, dynamic *Network Operations Plan (NOP)* representing the entirety of all RBTs which are mutually dependent.

  SESAR does, unlike NextGen, specify that there has to be a Network Manager (NM) who is responsible for the development, implementation and periodic maintenance of a common European NOP containing all negotiated RBTs. Yet, both SESAR and NextGen do currently not define which entity or person will be responsible for the operational editing of NOPs when it comes to pre- or in-flight RBT adjustments. Moreover, it is unclear whether this responsibility might be place on other ATM stakeholders, e.g. ATC entities.

---

[2] JPDO /82/

[3] Mr Tenenbaum is SESAR Deputy Contribution Manager and manages the EUROCONTROL research and development contribution to the SESAR Joint Undertaking (SJU); and Mr Dunkley is SESAR Joint Undertaking (SJU) Programme Manager and in leading responsibility for the entire WP 11 (WP 11.1: *Flight and Wing Operation Centers* and WP 11.2: *Meteorological Information Services*).

[4] Mr Ibrahim Gülcan is manager of the Air Berlin OCC in Berlin, Germany; Mr Hermann Lindner is, on behalf of Air Berlin, responsible for political affairs and contact person for SESAR; and Mr Helge Güldenberg is manager of the Deutsche Lufthansa HUB Operations Center in Munich, Germany.

- The process of OCC-internal operational decision-making will become more complex as the intended CDM-environment requires more system performance and increases OCC personnel workload. This is due to the fact that the resource *time* will become a stringently limiting factor as all decisions affecting the negotiation of 4DTs will have to be made collaboratively; this, however, requires a certain amount of time which is only available limitedly during the phases of tactical planning and operations control as late decision-making will in most cases result in disruptions. Therefore, the usage of *Decision Support Tools (DST)* will become inevitable. However, as ATM resources like airways and airport slots are only limitedly available due to capacity constraints, short-term changes to the NOP will only be feasible by means of *Resource Bidding*. This principle - geared to the concepts of stock trading and CDM – will be a substantial part of DST and generally enable airspace users to buy and/or sell ATM resources which have already been allocated on short notice by using DST.

  Yet, SESAR and NextGen do currently not specify how to handle situations where time for solution-finding is running out and CDM does not bring suitable results. Moreover, neither SESAR nor NextGen currently provide definitions how operational ATM resource bidding and/or allocation shall take place and how individual flights can be prioritized, if necessary (e.g. medical emergency, fuel shortage).

- Both SESAR and NextGen foster a shift in focus when it comes to the functional and operational integration of OCCs into operational decision-making processes; the cooperation of ATC entities and cockpit crews shall be expanded whilst the OCC is only regarded as being responsible for providing decision support to the cockpit crews. Yet, this will not only result in insufficiencies for airspace users, but also for the overall ATM system. This is due to the fact not individual cockpit crews, but the OCCs are responsible for the overall operational efficiency of their airlines; the accumulation of many little inefficiencies across all airspace users may possibly lead to severe inefficiencies throughout an entire ATM environment.

In summary, it can be stated that both initiatives do currently not account for the integration of OCCs into the respective ATM environments sufficiently as there are not many specifications provided regarding the processes of OCCs as well as their interaction with other ATM stakeholders. It is without doubt that the OCC-related provisions given so far will have to be detailed and revised as to ensure that the implementation of SESAR and NextGen meets the respective ATM initiatives' objectives and time frames. Otherwise, the identified conceptual inadequacies will endanger these projects' common objective of increasing ATM efficiency.

1 FUTURE AIR TRAFFIC DEVELOPMENT

Considering the globally growing passenger and cargo air traffic volume, it becomes increasingly important to utilize the existing airspace efficiently in order to ensure that the need for capacity is always satisfied whilst given safety standards are observed at all times. Increasing capacity in a given airspace means allowing more and/or larger aircraft to operate in the same volume of air so that more payload can be transported in the same amount of time. In order to maintain recent ICAO safety standards, the overall safety of aircraft operations has to be increased accordingly.

This chapter summarizes the expected market outlook of air traffic development, both on the global as well as the European and U.S. American scale. As a consequence, this chapter shows off the need for Air Traffic Management (ATM) initiatives SESAR and NextGen.

1.1 GLOBAL MARKET OUTLOOK

Airbus /1/ and Boeing /2/, the two world-leading aircraft manufacturers, both independently claim that the demand for air travel is continuing to grow significantly over the next two decades, perpetuating the trend of the past 40 years. As shown in Figure 1, even events with a huge impact on the global aviation industry – like the first and second oil shock (1971 and 1979/80), the 1990/91 Gulf War, the 9/11 terrorist attacks (2001), the 2002 SARS outbreak or the 2007/08 Global Financial Crisis – could not significantly bar the aviation business from doubling its transport performance roughly every 15 years. Thus, both Airbus and Boeing forecast an estimated annual worldwide air traffic growth between 4.7 and 5.1% in the passenger segment. Cargo traffic is expected to increase by an average of 4.9 to 5.2% per year. In contrast, the world Gross Domestic Product (GDP) is estimated to grow by only 3.2% annually [Boeing /2/, p. 3].

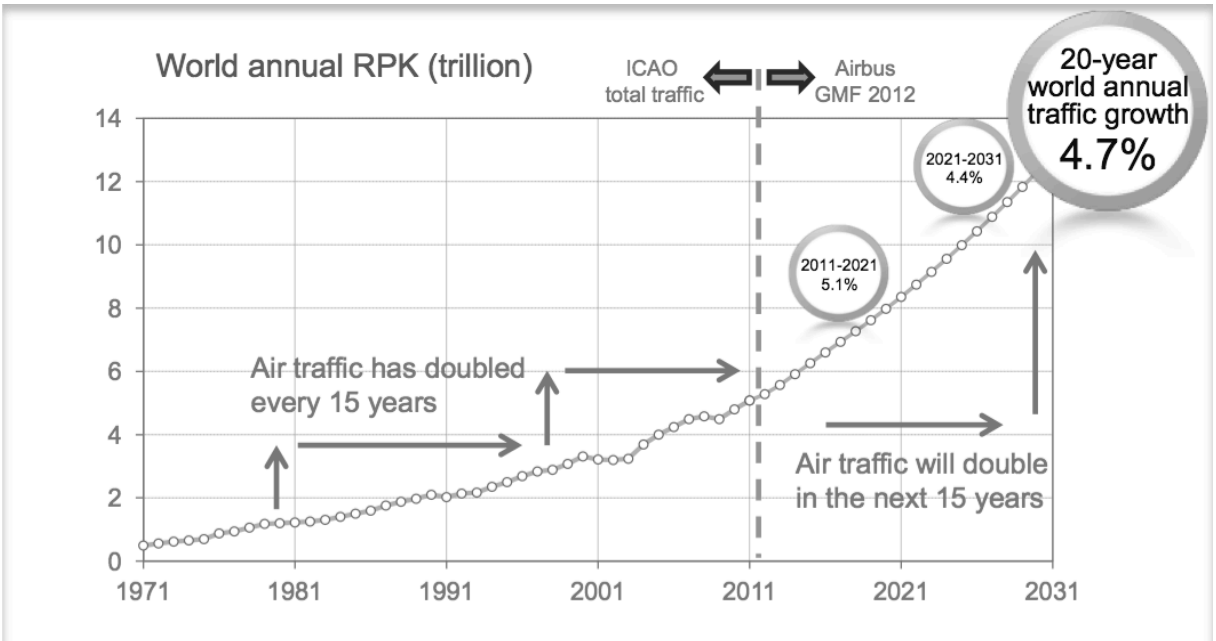


Figure 1: World annual RPK growth (1971-2031)[5]

If the entire aviation industry today was a country, it would be – in terms of GDP – number 19 on the list of most productive countries [Airbus /3/, p. 31]. Due to the expected exponential growth of 4.7% annually, the 2011 amount of approximately 5.1 trillion RPK per year will have doubled 15 years later (2026) and increased by 150% in another five years in 2031, as

[5] Airbus /3/, p. 25

depicted in Figure 1. This equals a total amount of approximately 12.8 trillion RPK flown in 2031.

This growth in terms of RPK is accompanied by a rising amount of passengers. It is estimated that between 2011 and 2031, the number of passengers transported will increase by 4.0% per year [Boeing /2/, p. 4]. In order to be able to satisfy the growing demand for air transportation, airlines will try to adapt the supply accordingly by using more and/or larger airplanes. Figure 2 shows, sorted by aircraft size, a comparison of aircraft in service in 2011 and prediction for the year 2031 from Boeing:

Airplanes in service 2011 and 2031

Size	2011	2031
Large	790	1,030
Twin aisle	3,710	9,110
Single aisle	12,610	27,430
Regional jets	2,780	2,210
Total	**19,890**	**39,780**

Demand by size 2012 to 2031

Size	New airplanes	Value ($B)*
Large	790	280
Twin aisle	7,950	2,080
Single aisle	23,240	2,030
Regional jets	2,020	80
Total	**34,000**	**4,470**

*$ values throughout the CMO are catalog prices.

Figure 2: A/C in service (2011 and 2031)[6]

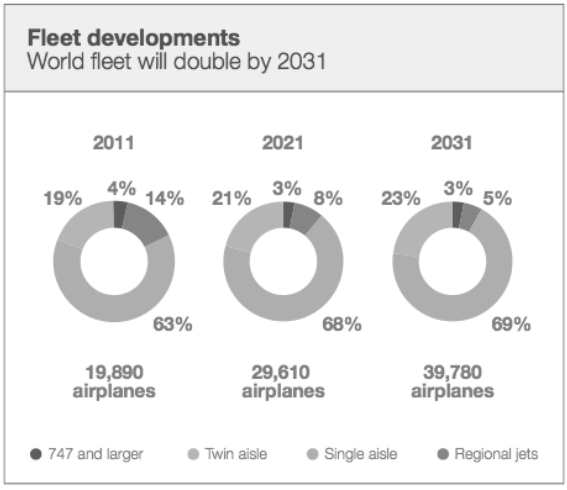


Figure 3: Fleet development (2011-2031)[7]

The overall amount of aircraft in service will, as seen from 2011, double until 2031 and reach approximately 39,780 units. During the same period of time, the need for newly built aircraft amounts to 34,000 units which indicates that 41% of currently existing aircraft (19,890 in 2011) will be replaced by 2031. The remaining 59% of "the new deliveries will reflect growth in emerging markets and evolving business models" [Boeing /2/, p. 15].

Furthermore, Figure 3 gives an overview of the current distribution of different-sized aircraft and how it is expected to alter until 2021 and 2031, relative to the overall amount of serviceable aircraft. It is obvious that, while the shares of long-range (type Boeing 747 and larger) and twin aisle aircraft nearly stay the same, the relative amount of single aisle aircraft is going to increase from 63% in 2011 to 69% in 2031. According to [Boeing /2/, p. 4], this reflects the "growth in emerging markets, such as China, and the continued expansion of low-cost carriers throughout the world". Meanwhile, the share of regional jets will decrease from 14% in 2011 to only 5% in 2031, reflecting the general airlines' intentions to continue expansion into international markets and becoming more cost-efficient by using well-loaded single aisle aircraft instead of pour-loaded regional jets when it comes to short-haul flights. [Airbus /3/, p. 16] lists the following global main drivers for this development as follows:

- **Rising world population**: In 2010, the total population on earth amounted to 6.90 billion people. According to United Nations estimations, this number will increase until 2030, when 7.87 to 8.78 billion people – depending on the supposed growth rate – will inhabit the earth.[8]
- **Growing number of mega-cities**: The amount of metropolitan areas exceeding 10 million inhabitants and/or having a population density of more than 2,000 inhabitants

[6] Boeing /2/, p. 4

[7] Boeing /2/, p. 15

[8] United Nations /4/

per square kilometer is constantly increasing, especially in Asia. Today, there are 28 such cities, 16 of them in Asia.[9] The United Nations estimate that 4.90 billion people – approximately 71% of today's entire world population – will be living in mega-cities by 2030.[10] This ongoing urbanization will lead to a further increase in the amount of mega-cities, all of them being in urgent need of adequate air transport supply in order to remain economically attractive and satisfy their citizens' and investors' needs.

- **Emerging markets and ongoing liberalization**: Due to liberalization, new airlines are able to enter emerging markets and start competition with established, often government-subsidized (flag) carriers (e.g. Asia, Africa and Latin America). A direct result of this competition is a decrease in ticket prices; it also serves all passengers since they can choose the airline which meets their expectations and needs the most. Furthermore, there are more destinations passengers can travel to. As the ticket prices drop, the demand for air transport rises, more tickets are sold and the entire market benefits. This development is also stimulated by the possibility to establish low cost carriers (LCC) in liberalized markets. This is why emerging regions such as multiple parts of Asia-Pacific or Africa, where liberalization is still taking place or has not taken place yet, will generate more air traffic over the next decades. Figure 4 shows this effect using the example of Morocco which joined the European Union Open Skies Agreement in 2007: the amount of Available Seat Miles (ASM) offered weekly increased significantly due to liberalization, allowing foreign LCC to operate within Moroccan airspace and raising the 10-year-average annual air traffic growth rate to 11.5%.

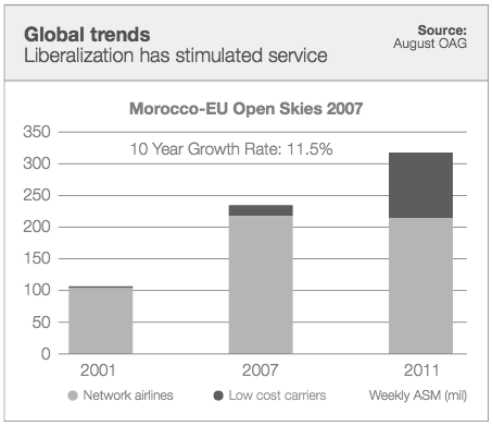


Figure 4: Effects of the liberalization of Moroccan airspace[11]

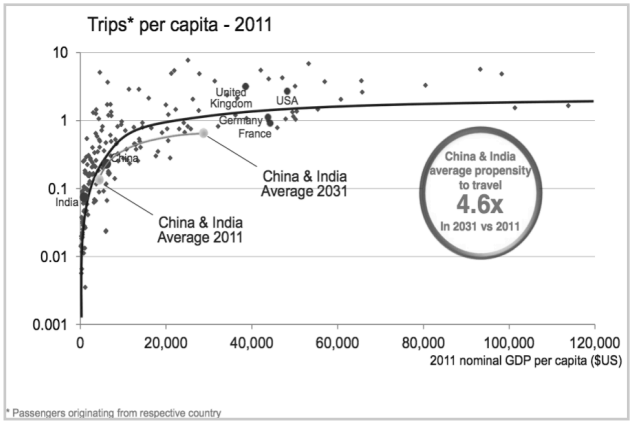


Figure 5: Trips per capita over nominal GDP per capita (2011)[12]

- **Growing middle class**: Due to the generally increasing and more evenly spread private and public wealth (especially in emerging countries) as well as the rising world GDP, people all over the world are able to fly more often, both for private and business-related reasons. This development is supported by the ongoing internationalization of markets, business relations and tourism.

  Figure 5 depicts the amount of trips conducted per capita in correlation to the nominal GDP per capita for different countries, as in 2011. Furthermore, it illustrates how this situation will look like in 2031, using the example of China and India combined (arithmetic average). In twenty years, the average Chinese or Indian will travel approxi-

[9] Brinkhoff /5/

[10] United Nations /6/

[11] Boeing /2/, p. 11

[12] Airbus /3/, p. 18

mately 4.6 times more often due to the increase in nominal GDP per capita from approximately 6,000 $US to 30,000 $US. A more general estimation for the global development of what is called *middle class* is given in Figure 6. According to [Airbus /3/, p. 18], persons belonging to *middle class* are defined as members of "households with daily expenditures between $10 and $100 per person".[13] Whereas in 2011, only 30% of the world's population can be categorized as being middle class, it will be approximately 60% in 2031. While the number of middle class members in Europe, the Commonwealth of Independent States[14] (CIS) and North America is expected to almost stay the same as in 2011, the amount of this group of people coming from the Asia-Pacific region will rise fivefold by 2031.

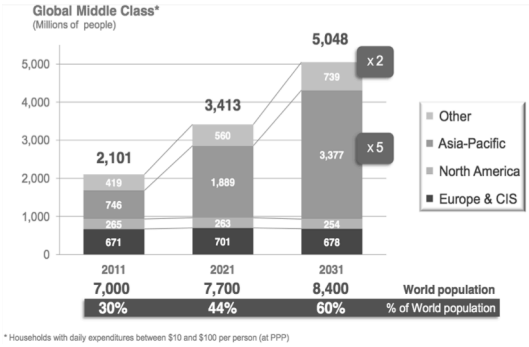


Figure 6: Development of global middle class (2011-2031)[15]

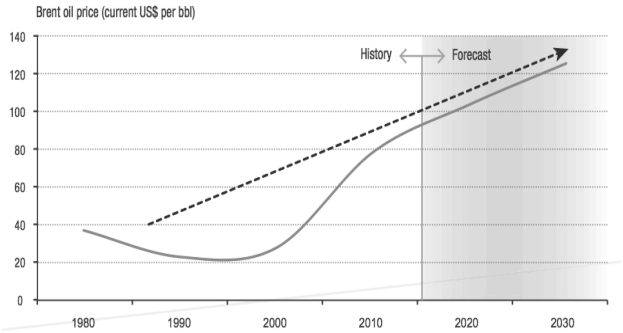


Figure 7: Crude oil price development (1980-2030)[16]

- **Rising crude oil prices and increasing ecological awareness**: The expected increase in Brent crude oil prices – as depicted in Figure 7 – is primarily caused by the natural shortage of crude oil as a non-renewable source of energy. As demand for aviation services and fuel has constantly risen throughout the last decades and will continue to do so over the next two decades, the supply will stagnate due to the lack of exploitable, newly found crude oil reservoirs. As a consequence to increasing prices, a replacement of less eco-efficient, highly fuel-consuming aircraft will take place in order to compensate rising fuel prices by reducing the amount of fuel burnt as much as possible. Additionally, there might be new propulsion technologies available, using modern, more reliable and price-stable power sources, e.g. biofuels, hydrogen or solar energy. This would generate thrust whilst minimizing or even neutralizing the amount of pollutants. This development does not only represent a technological but also both an ecological and sociological need: there is a globally increasing awareness on how to use, share, and distribute the earth's non-renewable energy sources. Safeguarding the environment by reducing human-made pollutant emissions and using natural resources in a more responsible, sustainable way is an essential cornerstone in human evolution which still has to be achieved. Reducing aircraft noise and its impacts on human beings and wildlife is also an important point on this agenda.

All in all, there are many major reasons why the amount of air traffic conducted globally – and thus the total number of aircraft in service – will significantly increase over the next decades. But, due to different regional growth rates – depending on the individual transportation

[13] This definition is based on the economic principle of Purchasing Power Parity (PPP) which serves to estimate the adjustment needed on the exchange rate between two countries so that the "exchange rates between [the two] currencies are in equilibrium [ensuring that] their purchasing power is the same in each of the two countries. This means that the exchange rate between two countries should equal the ratio of the two countries' price level of a fixed basket of goods and services" [Antweiler /7/].

[14] Regional organization of countries formerly belonging to the Soviet Union.

[15] Airbus /3/, p. 43

[16] Airbus /1/, p. 18

market characteristics and prevailing airline strategies – regions develop with varying growth rates, resulting in a varying demand in aviation. According to [Airbus /1/, p. 10], more than 60% of the predicted overall global air traffic "will involve the advanced aviation markets, primarily North America and Europe". [Boeing /2/, p. 18] states that "markets in North America and Europe are shaped by aggressive growth of low-cost carriers and the need to replace aging airplanes in the fleets of established network carriers. Demand is strongest for single-aisle airplanes in these markets".

In order to be able to evaluate the necessary European and U.S. American ATM changes, the following two Chapters, 1.2 and 1.3, highlight the specific situations Europe and the USA will have to face throughout the next two decades in terms of growing air traffic.

1.2 EUROPEAN MARKET OUTLOOK

According to [Boeing /2/, p. 26], the European[17] aviation business "remained strong in 2011, despite uncertainties from the sovereign debt crisis and the lingering threat of recession. Europe's GDP increased by 1.8 percent in 2011 compared to 2010". This is, according to [World Bank /11/], by far less than the global average GDP growth which increased by 2.7% in 2011.

Although European air traffic is not as fast-growing as other markets, Boeing claims that the amount of RPK has risen by 4.1% in 2011. Considering the cargo traffic, there has been a 4.9% increase in Revenue Tonne Kilometers (RTK).

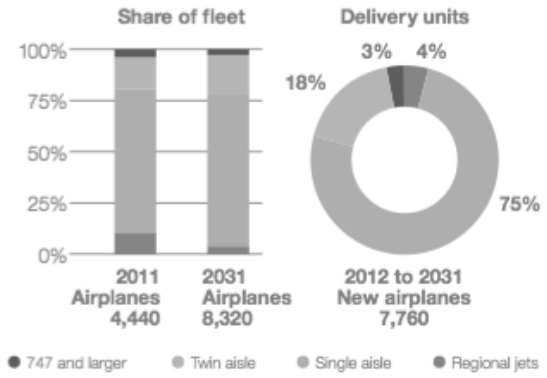


Figure 8: European fleet development (2011 and 2031)[18]

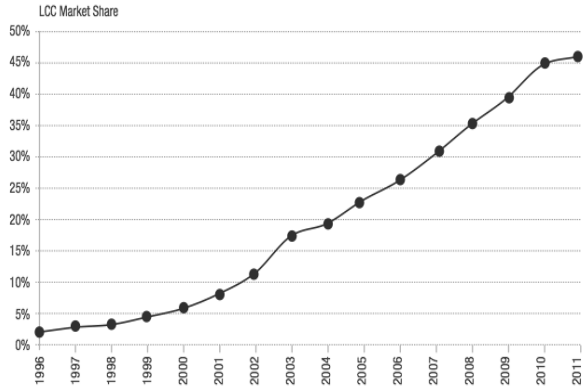


Figure 9: Intra-European LCC share (2000-2011)[19]

As shown in Figure 8, European airlines had 4,440 registered aircraft in service in 2011, 3,160 of which were (71.2%) single aisle, followed by 680 twin aisle (15.3%), 410 regional jets (9.2%) and 190 type 747 aircraft (4.3%).

[Boeing /2/] expects that European airlines will have to acquire 7,760 new aircraft during the fiscal years 2012 to 2031, 75% (5,800) of them single aisle, 18% (1,440) twin aisle, 4% (320) regional jets and 3% (200) type 747 aircraft. This is mainly due to both the need to replace old aircraft by more modern ones and in order to satisfy the European air traffic demand, which is expected to grow 4.1% per year in the forecast period. Notwithstanding the fact that the global aviation business is expected to develop considerably faster during the next two decades – approximately 4.7-5.1% annually in terms of RPK –, the European aviation busi-

[17] Unless otherwise declared, all statements about Europe in this Chapter refer to Europe as a geographical region, not as a political union.

[18] Boeing /2/, p. 26

[19] Airbus /1/, p. 81

ness will also remain an important global market since approximately 970 billion $US will be spent on new aircraft in this period of time. Thus, in 2031, there will be approximately 8,320 registered European aircraft in service, 6,120 of them (73.5%) single aisle, followed by 1,630 twin aisle (19.6%), 340 regional jets (4.1%) and 230 type 747 aircraft (2.8%).

Figure 8 also indicates that the share of aircraft types is going to alter during the forecast period: the share of single aisle and twin aisle aircraft is estimated to increase by 2.3% respectively 4.3% whilst both the shares of regional jets and type 747 aircraft will decline by 5.1% respectively 1.5%. This is due to the following two main developments currently taking place in Europe, as stated by [Boeing /2/, p. 26]:

- **LCC to gain market shares**: Due to the liberalization of the European airspace, which took place from 1987 to 1992 following EEC Regulations No. 2407/92, 2408/92 as well as 2409/92 – all together having been consolidated by EC Regulation No. 1008/2008 in 2008[20] – Low Cost Carriers (LCC) were allowed to access the European air traffic market. As depicted in Figure 9 (p. 5), this led to a continuous increase in the LCC market share, starting at approximately 2% in the fiscal year (FY) 1996 and reaching 46% in 2011. [Boeing /2/] expects this development to continue during the next two decades, albeit at lower annual growth rates. Thus, LCC will continue to take over short-haul, intra-European flights and will establish more point-to-point connections between profitable destinations, resulting in an increased demand for single aisle aircraft.
- **Network Carriers to expand into long-haul flights**: In direct contrast to the LCC development depicted above, network carriers will have to change their business strategies, shifting their focus from offering intra-European short-haul flights and, instead, offering more long-haul flights based on hub-and-spoke operations. In order to be able to do so, they will continue to rely on joining global alliances, such as Star Alliance and One World. This enables them to share less profitable but necessary feeding connections and thus, enhancing their spatial radius of operations while maximizing the Seat Load Factors (SLF) on those routes.

A generic comparison of hub-and-spoke and point-to-point operations is given in Figure 10.

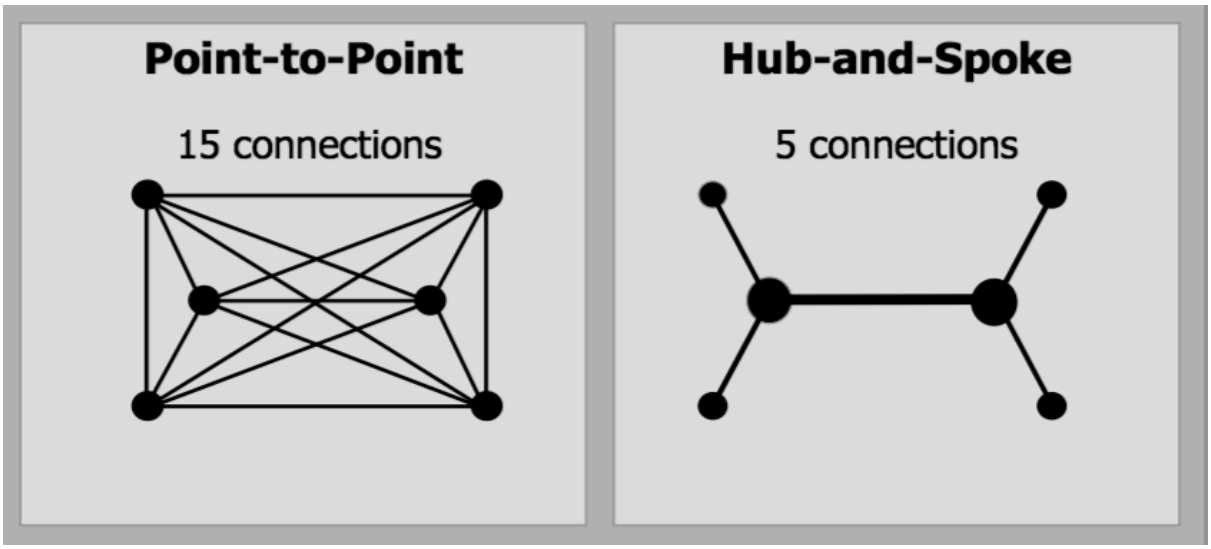


Figure 10: Point-to-Point vs. Hub-and-Spoke connections[21]

[20] European Parliament /8/

[21] Hüttig /9/

Whereas it takes 15 connections to connect six destinations using Point-to-Point connections, it only takes five connections to do so using Hub-and-Spoke connections. This is why Point-to-Point connections are more attractive for LCC, since they do not have to operate cost-intensive hubs and join alliances in order to be able to serve their multiple destinations in a cost-efficient manner. This is because short-haul flights, due to a higher design payload-fuel-ratio, are generally more profitable at lower SLF than longer-haul flights.[22] Network carriers, however, benefit from conducting Hub-and-Spoke operations and joining alliances since long-haul flights require much higher SLF than short-haul flights in order to be profitable. Thus, sharing flights with an otherwise low average SLF with allied airlines enables network carriers to raise the overall profit gained from all connections offered throughout the entire airline's network. This is due to the fact that most of the passengers booked on one flight are forced to continue their travel using a more profitable connecting flight due to the co-centric network structure.

According to [EUROCONTROL /10/, p. 16], 9.78 million controlled IFR flights have been conducted in Europe in 2011. Taking into account the most likely Compound Annual Growth Rate (CAGR) of 2.8% as estimated by [EURCONTROL /13/, p. 9], the future number of IFR flights conducted within the boundaries of the European Union can be calculated as follows:

$$a(t) = Ae^{rt}$$

Formula 1: Exponential growth function

where:

- t: time (0-20 years)
- A: initial amount (IFR flights conducted in 2011)
- r: annual average IFR flights growth rate (2.8%)
- a(t): amount of IFR flights conducted after a certain time *t*

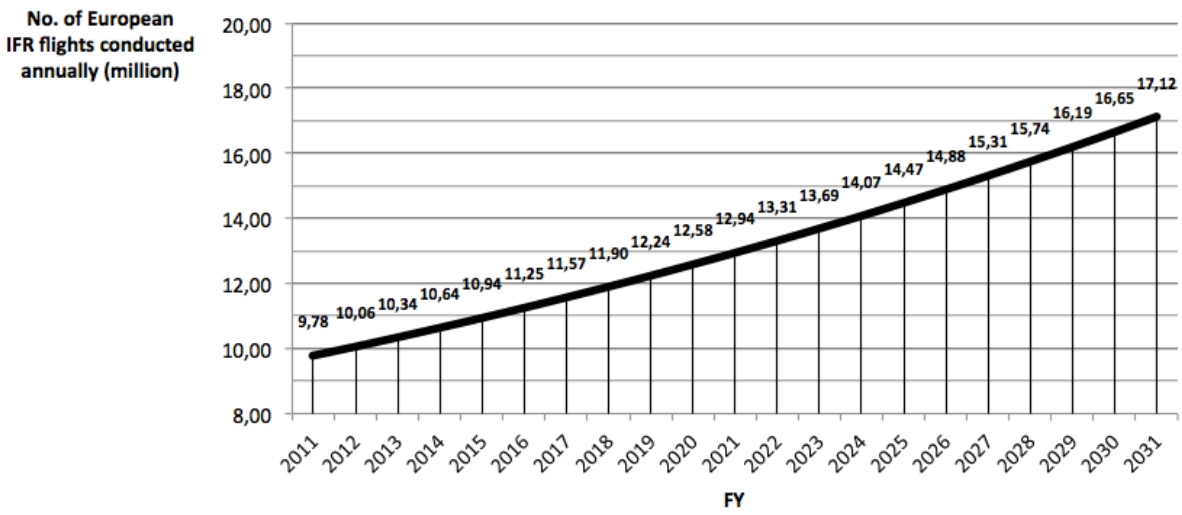


Figure 11: Annual amount of European IFR flights (2011-2031)[23]

[22] Hüttig /9/

[23] Author's own calculation

Figure 11 shows the resulting graph. In 2031, there will be roughly 17.12 million IFR flights conducted in Europe which equals a growth of 75.1% over 20 years. This does not meet the average global aviation growth rates of 4.7-5.1% p.a. as described in Chapter 1.1, but still represents a significant development burdening the ATM.

1.3 US AMERICAN MARKET OUTLOOK

In 2011, more than 730 million passengers have been counted aboard flights from, to and within the territories of the United States of America (USA), securing the domestic US aviation markets' spot as largest in the world.[24] The ongoing debt crisis, high unemployment rates of about 8.1% on average and even the recent European sovereign debt crisis influenced the national GDP negatively in 2011, which only grew by 1.7%.[25] However, as the unemployment rate is expected to continue to decline – in comparison to 2011, 10.0% of employable US citizens were unemployed in 2009 – and average household income levels are expected to rise in return, [Airbus /1/, p. 89] "projects an increase in the GDP growth rate in the US, peaking at 2.7% in the fourth quarter of 2014 before returning to a stable growth rate of about 2% annually". [Boeing /2/, p. 25] forecasts a more optimistic development, estimating that the long-term US GDP will grow by 2.6% p.a., as illustrated in Figure 13.[26]

In 2011, the average US American citizen spent about 490 $US for travel expenses, which represents the highest average amount of money spent for travelling since 1981.[27] Thus, the growing GDP will have an impact on the US aviation market, since the average expenditures for travel per capita will continue to increase. This will happen in correlation with improving income situations, also resulting in an increase in the amount of money spent for flight tickets per capita. In return to a higher demand, the number of flights conducted will rise.

As depicted in Figure 12 and Figure 13, 6,650 US-registered aircraft were in service in 2011, 3,730 of them (56.1%) single aisle, followed by 1,030 twin aisle (15.5%), 1,770 regional jets (26.6%) and 120 type 747 aircraft (1.8%).

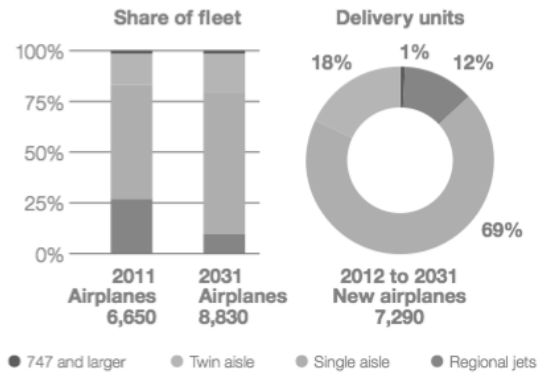


Figure 12: US fleet development (2011 and 2031)[28]

Growth measures	
Economy (GDP)	2.6%
Traffic (RPK)	2.8%
Cargo (RTK)	4.5%
Airplane fleet	1.4%

Market size	
Deliveries	7,290
Market value	$820B
Average value	$110M

	New airplanes	Share by size
Large	40	1%
Twin aisle	1,320	18%
Single aisle	5,040	69%
Regional jets	890	12%
Total	7,290	

	2011 Fleet	2031 Fleet
Large	120	110
Twin aisle	1,030	1,740
Single aisle	3,730	6,090
Regional jets	1,770	890
Total	6,650	8,830

Figure 13: US aviation market key indicators (2011 and 2031)[29]

[24] Airbus /1/, p. 88

[25] World Bank /11/

[26] This deviation – from the author's point of view – can be explained by the fact that Boeing, being an US American manufacturer, is strongly reliant on the recovery of the US American industry and a positive US GDP development since domestic orders for both civil and military customers correlate, more or less, with the country's economic development. [Boeing /2/] itself, however, does not explicitly explain this significant deviation. Therefore, the data given by [Airbus /1/] seem to be more reliable.

[27] Airbus /1/, p. 89

[28] Boeing /2/, p. 25

By 2031, this situation will have altered significantly: 8,830 registered US aircraft will be in service, 6,090 of them (69.0%) single aisle, followed by 1,740 twin aisle (19.7%), 890 regional jets (10.1%) and 110 type 747 aircraft (1.2%).

Consequently, the share of aircraft types is going to change significantly throughout the forecast period: the share of single aisle and twin aisle aircraft is estimated to increase by 12.9% and 4.2% respectively whilst both the shares of regional jets and type 747 aircraft will decline by 16.5% and 0.6% respectively. This results in a demand for 7,290 new aircraft in total, 69% of them (5,040) being single aisle, 18% (1,320) twin aisle, 12% (890) regional jets and only 1% (40) type 747 aircraft.

[Airbus /1/, p. 90] lists the following reasons for this development:

- **Share of domestic flights to decrease**: The share of domestic US flights will continue to decrease, following the trend of the last 10 years. Whereas in 2003, 73% of all flights conducted within US territories were domestic, this share dropped to 65% by 2011. This development will lead to a shifting demand in aircraft types, resulting in an increasing demand for single and twin aisle aircraft and a decreasing demand for regional jets. The amount of registered type 747 aircraft will almost stay the same, as US American airlines will have to compete with more cost-efficient foreign airlines when it comes to long-haul flights. Despite rising demand for those flights, US American airlines are not necessarily expected to profit.
- **Replacement of aging fleets**: In 2011, US American carriers had one of the oldest fleets in service of any region, with an average age of eleven years. Only Africa's fleet was older, with an average of 12 years. In order to be able to keep up with the global aviation business, major investments in replacing outdated US aircraft will be necessary.
- **Ongoing consolidation**: Whereas 19 US airlines conducted 90% of the annual domestic traffic in 1987, only seven did so in 2011. Thus, the last two decades were shaped by a multitude of mergers and acquisitions, resulting in obligations which still have to be fulfilled. This decreases the amount of assets available for further investments.

According to [FAA /14/] projections, the overall number of IFR flights within the US territories will increase by 2.4% annually. Based on Formula 1[30] and a total amount of 9.97 million IFR flights conducted in 2011 as stated by [RITA /12/], the overall number of IFR flights taking place in the USA in 2031 can be calculated as follows:

$$a(t) = Ae^{rt}$$

where:

- t: time (0-20 years)
- A: initial amount (IFR flights conducted in 2011)
- r: annual average IFR flights growth rate (2.4%)
- a(t): amount of IFR flights conducted after a certain time *t*

[29] Boeing /2/, p. 25

[30] Cp. p. 7

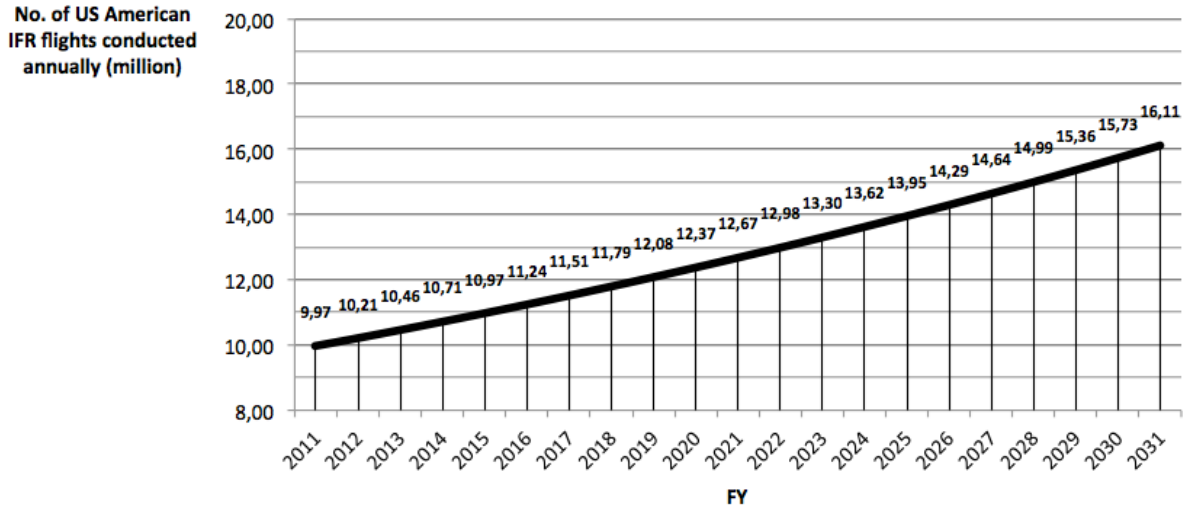


Figure 14: Annual amount of US American IFR flights (2011-2031)[31]

Figure 14 illustrates the future exponential growth of US American IFR flights as defined by the function given in Formula 1. According to these calculations, approximately 16.11 million IFR flights will be conducted within the territories of the USA in 2031. This equals an increase of 61.6% over 20 years. Whereas the amount of IFR conducted within the US will not grow as fast as that of European flights, this development still has to be regarded as significant. This is due to the fact that an efficient and orderly flow of air traffic, as demanded by [ICAO /15/, p. 2-2], cannot be maintained in the future without adequate ATM measures taken, since capacity restraints will lead to congestions, delays as well as cancelations and thus, to an insufficient air traffic supply overall.

1.4 COMPARISON BETWEEN THE EXPECTED FUTURE EUROPEAN AND US AMERICAN AVIATION MARKET DEVELOPMENT

Annex 1 lists, according to the key indicators discussed in Chapters 1.2 and 1.3, the major deviations in the development of European and US American aviation markets during the regarded forecast period. In general, it can be stated that, despite almost equal real and estimated GDP growth rates[32], the European aviation market will overtake the US American in terms of overall market growth, resulting from lower US American RPK as well as RTK growth rates over the next 20 years.

This market growth can also be recognized by comparing the absolute difference between IFR flights conducted within the USA and Europe today and in future. Whilst in 2011 6,650 aircraft were registered in the US and only 4,440 in Europe, about 190,000 more IFR flights have been taking place in the USA. In 2031 however, the number of US American and European aircraft is estimated to align, as there will be about 8,320 aircraft registered in Europe, compared to 8,830 in the USA. Calculations[33] show, that approximately 19.30 million IFR flights will be conducted in Europe in 2031, whilst in the USA, it will only be 16.11 million. Thus, within only 20 years, Europe will handle about 3.19 million more IFR flights p.a. than the USA, even though having approximately 510 less aircraft in service.

In summary, both the European and the US American aviation markets will continue to grow, albeit with differing CAGR. Compared to the global aviation business, both Europe and the USA will lose market shares since they will not be able to keep up with the average global

[31] Author's own calculation

[32] Cp. Footnotes 26 and 330

[33] Cp. Chapters 1.2 and 1.3

growth rates[34]. Emerging countries, especially in Asia, Africa and South America, are expected to experience further improvements in terms of economic prosperity and air traffic liberalization, which – in combination with increasing demand for air transportation due to rapidly growing populations – will enable them to realize average RPK growth rates of approximately 6% p.a., according to [Airbus /3/, p. 6] projections. This is more by far than the expected global average growth, as discussed in Chapter 1.1. In return, emerging aviation markets all over the world will encourage global competition, particularly in terms of medium- and long-haul flights.

This development, however, will most likely also affect the European and US American ATM. This is due to the fact that Europe and the USA will remain economically and culturally important regions during the next decades, even if particularly China's and India's political and economical powers will further increase. Moreover, even if the European and US American aviation markets lose their role as global market leaders, they will still serve as important hubs as they connect the emerging countries to the rest of the world and ensure the emerging countries' access to international markets.

This can be recognized by regarding Figure 15 and Figure 16: out of 42 global long-haul traffic airports that existed in 2011, 10 were European and 12 were US American, having a mutual share of 52.4%. Yet in 2031, there will be 19 European and 19 US American long-haul traffic airports out of 92 global ones, according to [Airbus /3/, p. 20f.]. By then, they will represent a mutual share of 41.3%.

Figure 15: Long-haul traffic airports (2011)[35]

Figure 16: Long-haul traffic airports (2031)[36]

While the percentage decrease of European and US American long-haul traffic airports can be explained with the developments discussed in detail above, it can be stated that the glob-

[34] Cp. Chapter 1.1

[35] Airbus /3/, p. 20

[36] Airbus /3/, p. 21

al amount of long-haul traffic airports will increase as a result of the growing need for more long-haul flights. In return, this leads to a higher global air traffic volume, also in Europe and the USA.

1.5 UPCOMING NEED FOR AIR TRAFFIC MANAGEMENT INITIATIVES

The developments described in the previous Chapters 1.1 to 1.4 will significantly impact the management of air traffic, both in Europe and the USA. [ICAO /16/, p. 1-4] defines Air Traffic Management (ATM) as "the dynamic, integrated management of air traffic and airspace including air traffic services (ATS), airspace management (ASM) and air traffic flow management (ATFM) – safely, economically and efficiently – through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions".

Thus, ATM in general provides the managing function between the ATM stakeholders, which include airspace users (airlines and military), Air Navigation Service Providers (ANSP) and airports. Its core function is to ensure that all flights, each of them scheduled by an individual airline between two airports and controlled by one or more ANSP, can be conducted in a safe, efficient and environmentally-friendly way in their entirety. The single functions and services adherent to ATM are depicted in Figure 17.

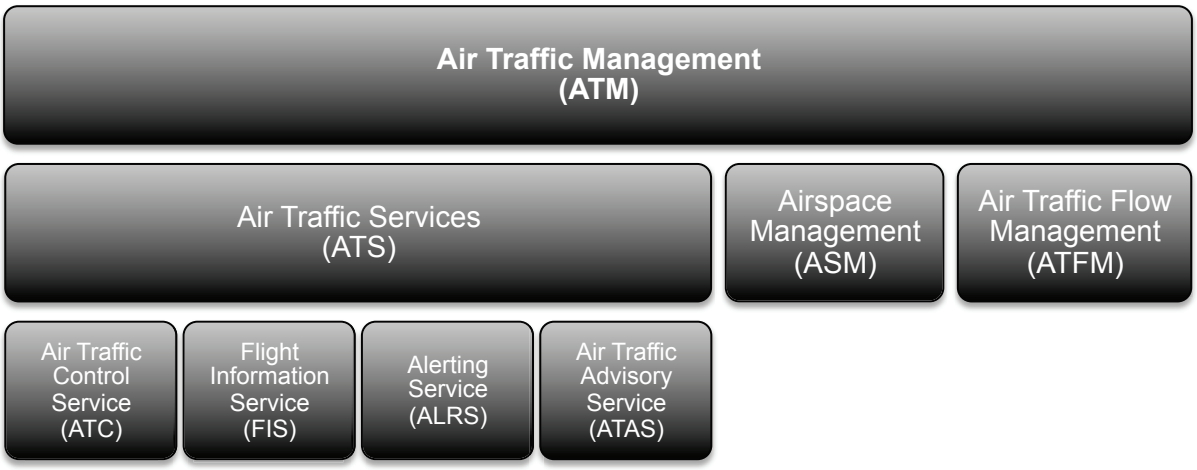


Figure 17: Air Traffic Management and adherent functions and services[37]

The following listing shall provide an overview of the single ATM main functions and services, as they are defined in both [ICAO /15/, p. 2-2] and [ICAO /16/, p. 1-1ff.]:

- **Air Traffic Services (ATS)**: ATS represent a main function of the ATM. The generic term ATS is used to describe the following four operational services provided by an ANSP:
    - **Air Traffic Control Service (ATC)**: A service provided for the purpose of preventing collisions between airborne aircraft, and – on the maneuvering area – between aircraft and obstructions. It furthermore serves to expedite and maintain an orderly flow of air traffic. ATC is the only ATS entity which is allowed to give clearances.
    - **Flight Information Service (FIS)**: FIS is provided by in order to advice and inform airspace users about safety-related issues and to maintain an orderly and efficient flow of traffic. In contrast to the ATC, the FIS must not give clearances.

[37] Author's own illustration; based on definitions given in [ICAO /16/, p. 1-1ff.]

- **Alerting Service (ALRS)**: A service provided to notify appropriate organizations regarding aircraft in need of search and rescue (SAR) aid, and assist such organizations as required.
- **Air Traffic Advisory Service (ATAS)**: A service provided within advisory airspace to ensure separation, in so far as practical, between aircraft which are operating on IFR flight plans. Advisory service must not deliver clearances but only advisory information.

- **Airspace Management (ASM)**[38]: The ASM is a main ATM function aiming at organizing and optimizing the airspace and its airways. ASM's primary objective is to maximize the utilization of available airspace by dynamic time-sharing and, at times, the segregation of airspace among various categories of users based on short-term needs. In future systems, airspace management will also have a strategic function associated with infrastructure planning.
- **Air Traffic Flow Management (ATFM)**: ATFM is a main ATM function established with the objective of contributing to a safe, orderly and expeditious flow of air traffic by ensuring that ATC capacity is utilized to the maximum extent possible, and that the traffic volume is compatible with the capacities declared by the appropriate ATS authority.

To become aware of the current ATM situation in both Europe and the USA, Annex 2 gives an overview of the performance of the European and US American ATM systems as of 2010. Regarding these data, it is evident that the current European ATM is heavily fragmented in contrast to the US American one. Both ATM systems cover almost the same airspace size. However, the US American ATM system has to handle a relative density of 2.2 flight hours per km^2 and year, whilst it is only 1.3 in Europe. Moreover, there is only one US American ANSP operating 20 ATM control centers, whilst there are 37 ANSP in Europe operating 60 ATM control centers. This can be attributed to the fact that the EU, unlike the USA, does not represent one single sovereign state.

The [European Commission /19/] estimates that the costs of fragmentation of European airspace amount to four billion EUR per year. Another outcome is that approximately 465.5 million km have been flown unnecessarily in the European airspace in 2010, since an average spatial difference to the geographically direct flight path of 49 km per IFR flight has been detected. This can mainly be attributed to the missing cross-boarder cooperation and common decision making within the European airspace, directly resulting from the fragmentation of airspace.[39]

Another problem, according to [European Commission /19/], is that the five biggest European ANSPs bear 60.3% of the total European gate-to-gate ATM and CNS provision costs and operate 54% of the European air traffic. The remaining 39.7% of gate-to-gate ATM and CNS provision costs, however, are borne by the other 32 European ANSPs. This leads to large divergences in the cost-effectiveness[40] of the individual ANPSs.

Figure 18 (p. 14) illustrates that the European share of arrivals delayed by more than 15 minutes[41] at the main 34 airports is 24.6%, whilst it is only 17.9% in the USA.

---

[38] Neither [ICAO /15/] nor [ICAO /16/] provide a definition for the term ASM, despite the fact of naming ASM as a main ATM function. Therefore, the definition given in [EUROCONTROL /17/, p. xix] has been (partly) adopted.

[39] For the USA, there is no such data available. Yet, [EUROCONTROL/FAA /25/, p. VII] states that "direct route extension […] [is] approximately 1 to 2% lower in the US for flights of comparable lengths".

[40] Definition ATM cost-effectiveness: average ATM costs per flight conducted

[41] According to [RITA /26/], a flight is regarded as been delayed when it arrives 15 minutes after the scheduled time of arrival.

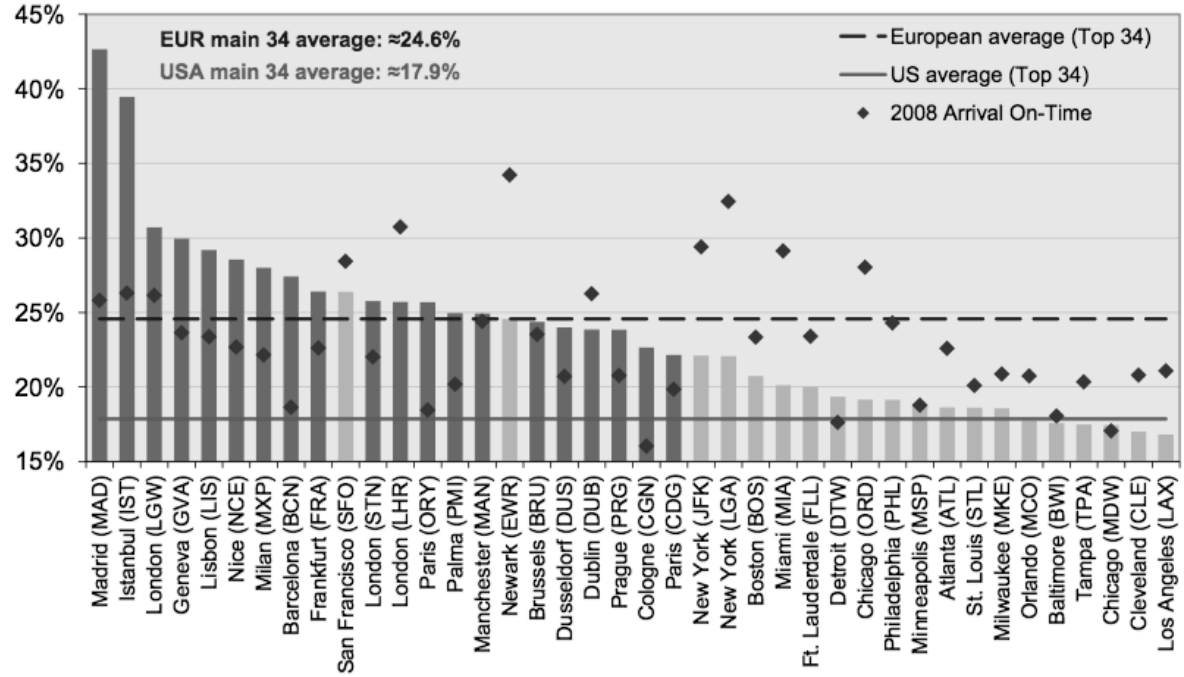


Figure 18: Share of arrivals delayed by more than 15 mins compared to schedule (2010)[42][43]

This must not exclusively be attributed to ATM insufficiencies, since there are generally several other reasons why an arriving flight can be delayed, but it mainly results from the fragmentation of European airspace as described above.

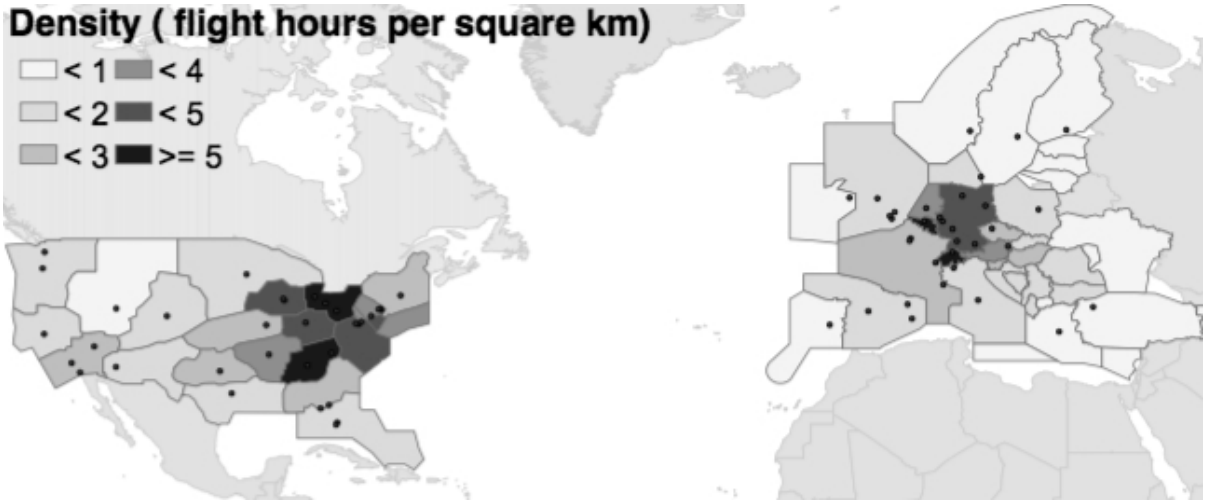


Figure 19: Traffic density in European and US American en-route centers (2010)[44]

Figure 19 shows the European as well as US American en-route centers as well as the relative traffic density, measured in flight hours per km^2 and year, within the single airspace blocks controlled from those centers. As one can see, the most used and complex areas can be found in Central Europe (especially Benelux States, Northeast France, Germany, and Switzerland) as well as in the Midwest and southern US territories (especially Cleveland, Chicago, Indianapolis, and Atlanta).

[42] EUROCONTROL/FAA /25/, p. 29

[43] Only the first 20 airports in Europe and the USA are shown.

[44] EUROCONTROL/FAA /25/, p. 8

Under the assumption that both the European and US American geographical area will remain their territorial size and considering the fact that aircraft performance as well as ICAO standard atmospheric conditions (ISA) determine the maximal usable flight level (FL) for all given flights, increasing air traffic volume will lead to airspace restraints due to growing relative traffic density as the associated airspaces themselves will not change in volume. Since the demand for air transportation continues to rise – as described in Chapters 1.1 to 1.4 – and ATM insufficiencies have been identified both in Europe and the USA, complex ATM optimization and modification measures will have to be taken in order to ensure that future air traffic can be handled at least as safely, efficiently and environmentally friendly as it is nowadays.

Therefore, both Europe and the USA separately passed their own ATM initiatives – *Single European Sky ATM Research* (SESAR) and *Next Generation Air Transportation System* (NextGen) respectively. The following Chapters 3 and 4 serve to highlight and compare these initiatives in order to be able to derive their possible future impact on Airline Operations Control Centers thereafter. Before this, Chapter 2 shortly describes the scientific approach of this thesis.

2 SCIENTIFIC APPROACH

The following two Chapters 2.1 and 2.2 serve to specify the objective and scope as well as the structure of this master's thesis.

2.1 OBJECTIVE AND SCOPE OF THIS THESIS

The overall objective of this master's thesis is to point out the impact of the current Air Traffic Management (ATM) initiatives SESAR (European approach) and NextGen (U.S. approach) on Operations Control Centers (OCC) as operated by commercial airlines. This encompasses those airlines providing scheduled passenger air transport services conducted according to the regulations provided by ICAO Standards and Recommended Practices (SARPs) – especially ICAO Annex 6, Part I – as well as European Commission Regulation (EC) No. 965/2012 (IR-OPS) and Federal Aviation Regulation (FAR) Parts 125 and 135.[45]

As to reach this objective, present SESAR and NextGen project documentation as well as secondary literature and scientific papers are examined as to be able to assess how future OCC workflows as well as OCC-cockpit crew interaction may possibly be influenced by SESAR and NextGen. Based on the provisions specified in SESAR and NextGen, schemes for future OCC integration into long- and short-term airline planning processes as well as pre- and in-flight OCC-cockpit crew workflow interaction are derived and analyzed. Adapted from that, a gap analysis is performed as to identify missing provisions and conceptual inadequacies in the SESAR and NextGen project documentations.

Remark: Due to an university agreement, the members of the Berlin Institute of Technology (TU Berlin) are not allowed to conduct military research and/or development. This master's thesis follows this provision strictly and will not specify or analyze military aspects of both SESAR and NextGen. But as both ATM initiatives, more or less, foster the integration of military airspace users into the development of the European and US American ATM systems, the author of this thesis cannot fully avoid mentioning interfaces and dependencies.

2.2 STRUCTURE OF THIS THESIS

The previous Chapter 1 served as an introduction to this master's thesis and described – based on regional as well as global long-term aviation business market forecasts – the political, economical, ecological, social and operational aspects of the upcoming need for ATM initiatives in general.

This Chapter 2, however, defines both the objective and scope of this master's thesis (Chapter 2.1) and specifies the associated scientific approach (Chapter 2.2). Therefore, the structure of the remaining Chapters of this master's thesis shall be explained in the following:

- **Chapters 3 and 4**: These Chapters provide a detailed, individual analysis of the operational concepts, key features and implementation aspects of the ATM initiatives SESAR and NextGen.
- **Chapter 5**: Based on the previous two Chapters, Chapter 5 aims at identifying similarities and differences between both ATM initiatives by comparing them, especially in terms of their fostered key features described within the respective SESAR and NextGen *Concepts of Operations* (ConOps).

[45] Whilst European commercial airlines are obliged to operate according to IR-OPS, US American airlines have to do so according to the provisions given in FAR Parts 125 and 135. Both can be regarded as been equivalent in large parts. Having come in force on 28 October 2012, IR-OPS replaced Regulation (EC) 859/2008 (referred to as *EU-OPS*). However, EASA member states may apply EU-OPS on an interim basis until 2014.

- **Chapter 6**: Subsequently, the setting, workflows and structures of today's OCCs as well as their integration into airline planning processes and the interaction of OCC-cockpit crew workflows are specified in Chapter 6. This happens by means of three self-defined scenarios which serve to demonstrate the OCC's current role in both pre- and in-flight disruption management.
- **Chapter 7**: Based on this, the results from the analysis of the SESAR and NextGen concepts (as described in the previous Chapters 3 to 5) are applied to current OCC workflows, structures and OCC-cockpit crew interactions in Chapter 7. It is examined in how far SESAR and NextGen make provisions when it comes to the integration of OCCs into the future ATM environments in particular. Based on these provisions, schemes for the possible future functioning of OCCs – as considered by the SESAR and NextGen ConOps – and their integration into both long- and short-term airline planning processes are derived and analyzed by means of the three self-developed scenarios given in Chapter 6. This allows for an assessment of the future influence of SESAR and NextGen on OCC workflows and structures as well as their pre- and in-flight interaction with cockpit crews. Resulting from that, gaps and missing provisions are identified and analyzed by means of a gap analysis.
- **Chapter 8**: Finally, Chapter 8 provides a conclusion of the results of this thesis and lists thematically-related issues which should be subject of further scientific research. This, e.g., encompasses the interoperability of SESAR and NextGen when it comes to transatlantic flight operations.

3 EUROPEAN ATM INITIATIVE – SESAR

As stated in Chapter 1, the current European ATM system has to be elementarily modernized as well as adapted in order to be able to fulfill tomorrow's requirements. Therefore, Chapter 3 shall give an overview of the ATM initiative the European Union has opted for.

3.1 THE SINGLE EUROPEAN SKY CONCEPT

According to the reasons depicted in Chapter 1.2, the European Union (EU), represented by the European Commission (EC), has decided to launch an ATM initiative called *Single European Sky* (SES) in November 2000. This happened across the backdrop, that the number of delayed European flights had risen severely due to airspace congestions and restraints in the 1990s.

Thus, a High Level Group has been appointed by the EC in order to draft a legislative package aiming at improving the recognized ATM problems. The result was presented to the EC at the end of 2001 and, after close examination, adopted as an European Union legal framework by the European Parliament (EP) and European Council in March 2004.[46] This framework, dubbed *SES I package* (SES I), consists of the following four basic regulations[47]:

- **Regulation (EC) No. 549/2004**: The framework regulation, laying down the framework for the creation of the Single European Sky
- **Regulation (EC) No. 550/2004**: The service provision regulation, on the provision of Air Navigation Services[48] in the Single European Sky
- **Regulation (EC) No. 551/2004**: The airspace regulation, on the organization and use of airspace in the Single European Sky
- **Regulation (EC) No. 552/2004**: The interoperability regulation, on the interoperability of the European Air Traffic Management network.

The framework regulation specifies the overall objective of the SES initiative as to "enhance current safety standards and overall efficiency for general air traffic in Europe, to optimise capacity meeting the requirements of all airspace users and to minimise delays".[49]

The successful implementation of SES, according to [EUROCONTROL /21/], is supposed to provide a lot of remarkable benefits. Thus, SES aims at:

- enhancing safety and efficiency of European air transport,
- decreasing delays by improving the use of available airspace and airport resources,
- improving services and reducing costs to passengers,
- improving integration of military systems into the European ATM system,
- providing demand-driven ANS provision, and
- enhancing cross-boarder coordination.

The following Subchapters 3.1.1 to 3.1.3 serve to highlight the means used in order to achieve these SES objectives.

---

[46] EUROCONTROL /18/

[47] European Commission /19/

[48] Abbreviation: ANS

[49] European Union /20/

3.1.1 IMPLEMENTATION OF FUNCTIONAL AIRSPACE BLOCKS

One of the major constraints prohibiting further growth of the European ATM system is the fragmentation of European airspace. Thus, the main objective of the SES initiative is to restructure the entire European airspace as to depart from the previous fragmentation by national boarders in support of newly built *Functional Airspace Blocks* (FAB). These represent combined, transnational airspaces created solely according to operational reasons, regardless of national boundaries. Since the EU also fosters regional cooperation, the SES initiative is not solely limited to member states of the EU, but also to third countries willing to associate with the SES legal framework. Hence, there will also be FABs encompassing third countries.[50]

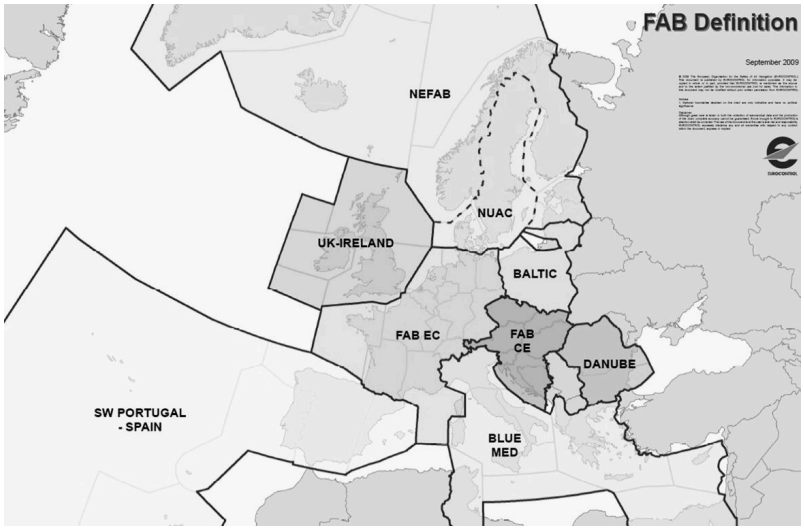


Figure 20: Functional Airspace Blocks (FAB) in Europe[51]

Once established, there will be nine FABs, as illustrated in Figure 20. Table 1 lists the countries associated to the individual FABs.

BALTIC: Poland, Lithuania	**FAB CE (Central Europe)**: Czech Republic, Slovak Republic, Austria, Hungary, Croatia, Slovenia, Bosnia and Herzegovina	**NUAC**: Denmark, Sweden
BLUE MED: Italy, Malta, Greece, Cyprus, Egypt, Tunisia, Albania, Jordan	**FAB EC (Europe Central)**: France, Germany, Belgium, Netherlands, Luxembourg, Switzerland	**SW (South-West)**: Portugal, Spain
DANUBE: Bulgaria, Romania	**NEFAB (North European)**: Estonia, Finland, Latvia, Norway	**UK-IRELAND FAB**: United Kingdom, Ireland

Table 1: European Functional Airspace Blocks (FABs) and associated countries[52]

[50] By name: Albania, Bosnia and Herzegovina, Croatia, Egypt, Jordan, Norway, Switzerland and Tunisia

[51] Austro Control /23/

[52] Author's own illustration

3.1.2 IMPLEMENTATION OF 4D TRAJECTORIES

In addition to harmonize the fragmented European airspace, SES also aims at standardizing the overall European ATM architecture and reinforcing ATM system interoperability. All in all, this shall provide the opportunity to conduct flights in a more time- and cost-efficient, economically friendly way, using so-called *4D trajectories* (4DT)[53].

According to [SESAR JU /40/], the use of such 4DTs will enable "airspace users to agree with […] ANSPs and airport operators on their preferred trajectory for a given flight in four dimensions (three spatial dimensions[54], plus time)". This happens in consideration of existing constraints of airspace and/or airport capacity. A business trajectory for an individual flight – once agreed by the airline, the ATC as well as the departure and arrival airport – becomes the official ATC flight plan for this flight. As all flights will be planed in advance, this concept allows to individually adapt the flight routes of all flights in a way so that no flight any longer will have to follow predefined, sub-optimally situated airways but can be – at the best – tailored to all the stakeholders' needs and existing constraints. The benefit resulting from this for every single flight can be compared to a meandering river which is being rectified in order to shorten the distance a ship has to cover in order to get from the river's spring to its mouth.

How this concept is going to improve the ATM can be recognized by regarding both Figure 21 and Figure 22 which show the difference between how a (conventional) trajectory looks today and how it will look when 4DTs will be used after the successful implementation of SES.

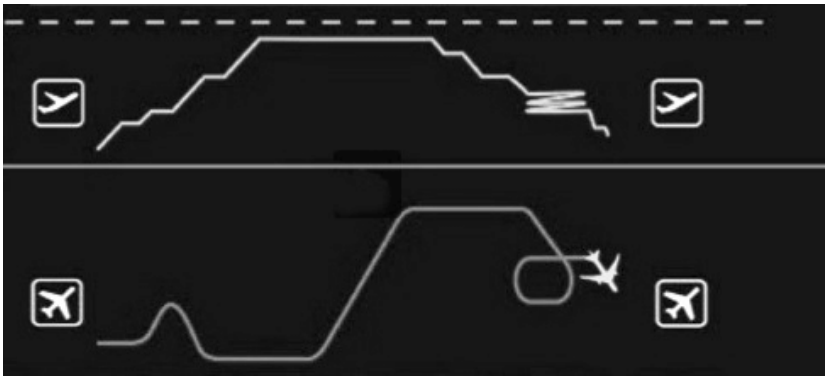


Figure 21: Conventional trajectory of a flight (as conducted nowadays)[55]

Airport D
(Departure)

Airport A
(Arrival)

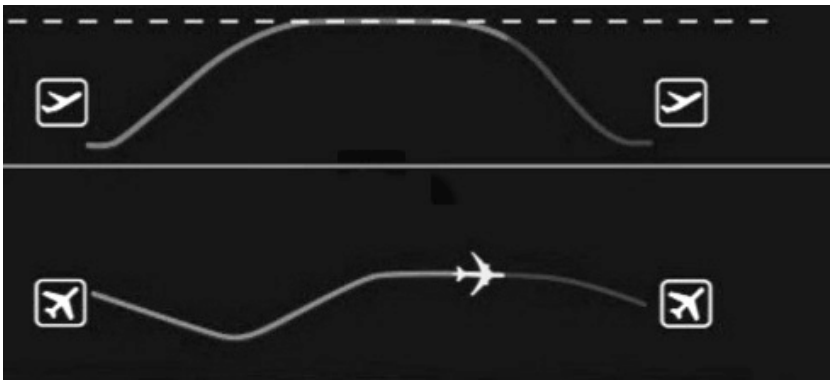


Figure 22: Business Trajectory (4DT) of a flight (as conducted when SES is established)[56]

[53] A 4D trajectory (4DT) is called *business trajectory* in the case of civil aviation and *mission trajectory* for military operations.

[54] These three dimensions represent the longitudinal and latitudinal position as well as the altitude of an aircraft.

[55] Deutsche Flugsicherung /39/; above: vertical flight profile, below: horizontal flight profile.

[56] Deutsche Flugsicherung /39/; above: vertical flight profile, below: horizontal flight profile.

The dashed horizontal lines, printed in the upper parts of both Figure 21 and Figure 22, indicate the maximal usable flight level (FL) for the regarded flight from airport D(eparture) to A(rrival). This FL is the most efficient one for cruise flight in terms of fuel consumption as the engines' individual performance is optimal for the atmospheric conditions at this FL. As denoted in Figure 21, flights conducted conventionally often cannot use this optimum FL as there are constraints which have to be considered, e.g. aircraft separation or airspace restrictions.

As depicted in Figure 22, 4DTs, however, aim at always offering the best possible flight route at the optimal altitude for the given and all other flights around. Thus, not only the aircraft's individual optimal FL will be available for use during cruise flight, but also the vertical flight paths for both the departure and descend flight phase will be smoother when 4DTs are used. This will save fuel as continuous ascents and descends consume less fuel than the step-wise adjustments conducted today.[57] Furthermore, the lateral guidance of aircraft will be more straight forward as avoiding other aircraft and restricted and/or otherwise unusable airspaces will occur in an optimal way since all correlating flight plans will be automatically optimized by algorithms hours or even days before the actual flights take place.

Despite this development, air traffic controllers will remain the last instance ensuring the safe, efficient and economically friendly flow of traffic.[58] Nonetheless their works' primary focus certainly will change from guiding aircraft to administrating them according to computations and routing proposals being made automatically. All in all, 4DTs facilitate more cost- and time-efficient flight routes as fuel usage and routing are optimized. In return, the environmental impact aviation can be reduced as the emission of carbon dioxides and other harmful pollutants will be lowered significantly.

3.1.3 SES – REVISION IN 2009

The implementation of SES is periodically reviewed by the European Commission (EC). In December 2007, an EC report[59] based on such a review showed that the SES I measures taken so far will not be sufficient enough in order to meet the requirements which the European ATM system will face in future.

For this reason, based on the report findings, the SES I package has been revised and extended in 2009 by Regulation (EC) No. 1070/2009 which aims at increasing the overall performance of the ATM system in Europe.[60] In order to be able to easily distinguish the old SES I legal framework from the new one, the entire package has been renamed *SES II package* (SES II). In addition to the SES I objectives, [EUROCONTROL /21/] states that SES II is aimed to:

- improve the performance of the ATM system through setting of Key Performance Targets (KPT),
- foster innovative technologies enabling the implementation of new operational concepts and increasing safety standards, and
- improve the management of available airport capacity.

As the SES concept itself and the objectives defined within solely represent a both ambitious and necessary political framework, a pan-European project had to be established which aims at implementing the entire SES concept in an accurate, orderly, efficient and economic manner. This project, which is not politically, but organizationally responsible for the SES imple-

[57] These concepts are called *Continuous Climb Departure* (CCD) and *Continuous Descend Approach* (CDA).

[58] Cp. Chapter 1.5

[59] European Commission: First Report on the Implementation of the Single Sky Legislation, as of December 2007

[60] European Commission /19/

mentation, is called *Single European Sky ATM Research programme* (SESAR). It is described in the following Chapter 3.2.

3.2 SESAR – OBJECTIVES AND PARTICIPANTS

In order to become able to efficiently realize the organizational, operational and technological requirements resulting from the politically prescribed objectives legally regulated in SES I and II, the Single European Sky ATM Research programme (SESAR) has been established in 2004. It is a collaborative project currently[61] managed by the SESAR Joint Undertaking (SESAR JU), which represents a Public-Private Partnership (PPP). Its main task is to efficiently coordinate and concentrate all necessary research and development efforts related to the successful implementation of the SES.

In order to be able to do so, the *European ATM Master Plan* was initially developed by the founding members of SESAR, the EU and EUROCONTROL[62]. It serves as the joint project schedule and roadmap for the entire SESAR implementation and is periodically adjusted to the development of the project by the SESAR JU.[63] Thus, it connects SESAR research and development with deployment. The recent issue of the European ATM Master Plan (Edition 2) was published in October 2012. According to [SESAR JU /27/, p. 5], it "takes benefit of the first results achieved by the SESAR programme to prioritize a set of essential changes that either provides significant performance benefits and/or forms a pre-requisite towards the implementation of the target concept [and provides] a basis for timely and synchronized deployments".

In order to be able to evaluate the implementation of SESAR, four *Key Performance Areas* (KPA) are focused, specifically capacity, safety, environment and cost-effectiveness.[64] These KPAs represent the performance-driven SES objectives and are defined by the following measurable *Key Performance Indicators* (KPI):

- "**Capacity**: A 3-fold increase in capacity while reducing delays, both on the ground and in the air (en-route and airport network), so as to be able to handle traffic growth well beyond 2020. The ATM System to accommodate by 2020 a forecasted 73% increase in traffic from the 2005 baseline, while meeting the targets for safety and quality of service.
- **Safety**: To improve safety levels by ensuring that the numbers of ATM induced accidents and serious or risk bearing incidents decrease. The traffic increase up to 2020 requires an improvement factor of 3, and for the long term a factor of 10 to meet the threefold in traffic.
- **Environment**: As a first step towards the political objective to enable a 10% reduction in the effects flights have on the environment by emission improvements through the reduction of gate-to-gate excess fuel consumption, minimizing noise emissions and their impacts for each flight to the greatest extent possible, minimizing other adverse atmospheric effects to the greatest extent possible.

[61] The current phase of the SESAR is managed by the SESAR JU. See Chapter 3.3 for further explanation.

[62] EUROCONTROL's contribution to SESAR, according to [EUROCONTROL /18/], is to assist the EU in "contributing to both the regulatory and the technology elements of the Single European Sky, by drafting implementing rules, guidance and technical regulatory material for the implementation of SES regulations, assisting Member States in exercising their regulatory functions, identifying needs for new regulations for the complex new ATM technologies and procedures delivered by SESAR".

[63] SESAR JU /27/, p. 5

[64] EUROCONTROL /35/

- **Cost-Effectiveness**: Halve the total direct European gate-to-gate ATM costs from 800 Euro/flight […] to 400 Euro/flight in 2020 through progressive reduction".[65]

The SESAR implementation concerns the entire European aviation business and its stakeholders, namely airport operators, ANSPs, civil and military airspace users and the aerospace manufacturing industry. As a matter of course, many of those parties are interested in taking influence and/or advantage as they are the ones who have to deal – on a more or less daily basis – with the results of the SESAR implementation.

Thus, the list of the 35 SESAR JU members and associate partners – depicted in Table 2 – reads as the who-is-who of the European aviation business. Moreover, there are eight consortia, in particular consisting of research organizations and universities, officially endorsed as associate partners.[66]

	Members	**Associate partners**
Founding Members	• EUROCONROL • European Union	n/a
Airport Operators	• AENA • NORACON • SEAC	• ONDA • SEA Aeroporti di Milano
ANSP	• DFS • DSNA • ENAV • NATS En Route	• Belgocontrol • Consortium LVNL • NATS Services • NAV Portugal • PANSA • Skyguide
Aerospace manufacturing industry	• Airbus • Alenia Aermacchi • Frequentis • Honeywell • Indra • NATMIG • SELEX ES • Thales	• AVTECH Sweden • Lockheed Martin UK • The Boeing Company • Thales Australia • Thales Raytheon Systems

Table 2: SESAR JU members and associate partners (2013)[67]

In order to be able to achieve the KPA targets listed above, investments as well as operational adjustments will be necessary. According to [EUROCONTROL /33/], the resulting total costs for the airspace users, airports operators and ANSPs are estimated to account for approximately 30 billion Euro.

Regarding Table 2, it interesting that not a single airspace user is listed as member or associate partner of the SESAR JU, although the implementation of SESAR both makes especially airspace users face huge costs and will urge them to adapt their operations by EU regulation.[68]

[65] EUROCONTROL /28/, p. 9

[66] SESAR JU /31/

[67] SESAR JU /29/ and /30/

[68] There is no explanation or reasons given for this matter of fact by the SESAR JU, even upon written inquiry; cp. Chapter 7.1 and Annex 6.

3.3 SESAR – PROJECT PHASES

The implementation of SESAR is currently being carried out in several steps. This is necessary since a transitional period is required in order to be able to synchronously harmonize the 60 different ATM systems[69] currently still operating in Europe. Moreover, as SESAR emphasizes aircraft self-separation, most of the aircraft in service need to be re-equipped to become compliant with SESAR's technological requirements.[70] Therefore, the implementation of SESAR takes place in three stages:

- **2005-2008: Definition Phase (completed)**: The main objective of the Definition Phase was to generate the initial edition of the European ATM Master Plan[71]. This phase built the foundation for the further implementation of SESAR. It laid down timetables, priorities as well as technological stages and was lead by both European Commission and EUROCONTROL. A large consortium of ATM stakeholders participated in this phase in order to be able to help define the future ATM environment they will have to operate in when SESAR is fully established. On 30 March 2009, the EU Transport Council approved the European ATM Master Plan by Council Decision 2009/320/EC.[72][73] Thus, the provisions defined in the European ATM Master Plan became legally binding for the following two stages.
- **2008-2013: Development Phase (currently active)**: After the completion of the European ATM Master Plan, the responsibility for its conducting and – in case to deviating project development – periodical adjustment have been handed over to the SESAR JU, following a Council Resolution from 9 October 2008.[74] Thus, SESAR JU has been officially consigned to manage the development of the SESAR project following the provisions of the European ATM Master Plan.[75] The costs of the Development Phase will be equally shared between the European Commission, EUROCONTROL and the remaining SESAR JU members[76] and are estimated to account for a total of 2.1 billion Euro.[77]
- **2014-2020(+): Deployment Phase (not yet active)**: This stage will focus on implementing the technological as well as operational changes having been designed during the Development Phase. In order to do so in a synchronized and operationally-viable way, [EUROCONTROL /35/] defines the following three complementary steps this transition will follow:
    - **Step 1 – Time-based Operations**: "[Step 1 builds] the basis of the SESAR Concept. It focuses on flight efficiency, predictability and the environment. The goal is a synchronized European ATM system where partners are aware of the business and operational situations and collaborate to optimise their operations. A prerequisite to Step 1 is the Deployment Baseline which consists of a set of operational and technical solutions that are already available and being deployed."

[69] Cp. Annex 2

[70] EUROCONTROL /32/

[71] Cp. Chapter 3.2

[72] EUROCONTROL /33/

[73] European Council /34/

[74] European Council /37/

[75] EUROCONTROL /33/

[76] As listed in Table 2; according to [EUROCONTROL /36/], only members, but not associated partners, have to contribute.

[77] EUROCONTROL /36/

- **Step 2 – Trajectory-based Operations (TBO)**: "[Step 2] focuses on a further-evolved flight efficiency, predictability and environment and adds capacity. The goal is a trajectory-based ATM system where partners optimise 'business and mission trajectories' through common 4D trajectory information and user defined priorities in the network."
- **Step 3 – Performance-based Operations (PBO)**: "[Step 3] is to achieve the full SES performance requirements. The goal is the implementation of a European high-performance, integrated, network-centric, collaborative and seamless air/ground ATM system."

As always when huge projects are conducted, it may happen that the scheduled time frame cannot be observed. Therefore, the Deployment Phase, which is officially determined to end in 2020, may be extended under the consideration of other necessary adjustments which may possibly occur during the implementation of SESAR.[78]

3.4 SESAR – KEY FEATURES

Following the three steps defined for the Deployment Phase[79], SESAR shall – once fully established – cover the six key features illustrated in Annex 3. These key features "describe the main strategic orientations" of the SESAR programme and are used to meet the SESAR KPA targets listed in Chapter 3.2.[80] The implementation of every key feature includes several essential operational changes, starting at the Deployment Baseline which requires ten essential operations changes. Following this scheme, the succeeding Step 1 requires eleven essential operational changes to be implemented in order to build the foundation necessary to implement the two following Steps 2 and 3. These both steps, however, require together 13 essential operational changes to be made. All in all, 34 essential operational changes have to be executed during the implementation of SESAR.

This chapter 3.4 serves to highlight those three key features relevant for OCC operations – as they are *4D Trajectory Management*, *System Wide Information Management* and *Network Collaborative Management & Dynamic Capacity Planning* – and will not cover all the six key features and corresponding technologies fostered by SESAR as this would go far beyond the scope of this thesis.

3.4.1 4D TRAJECTORY MANAGEMENT

In order to be allowed to execute the Trajectory-Based Operations (TBO) fostered by SESAR[81], an airspace user must agree to the trajectory that will be followed by the aircraft with all affected ATM stakeholders, which include the responsible ANSP(s) and departure as well as arrival airport operators, before the scheduled flight takes place. Existing airspace and airport constraints will be considered in this phase of Collaborative Decision Making (CDM). The negotiated 4D trajectory, describing the spatial 3D position of the aircraft at any given point in time during the entire flight from gate-to-gate, is called Reference Business Trajectory (RBT).[82] Thus, once agreed, the RBT "will become the reference trajectory which the airspace user agrees to fly and all the service providers agree to facilitate with their respective services" [Enea et al. /41/, p. 3]. It is obvious that the main intention of an airline will be to negotiate a RBT which serves to optimize both the fuel consumption and the off-block time (OBT).

---

[78] This is denoted by the plus sign $^{(+)}$ behind the year specification 2020.

[79] Cp. Chapter 3.3

[80] EUROCONTROL /38/

[81] Cp. Chapter 3.3

[82] Enea et al. /41/

The use of RBTs will enable civil airspace users to plan their flights more strategically and efficiently since they will know the exact flight routes of their aircraft before the actual flight takes place.[83] As airspace users will be able to predict their aircraft's positions and altitude at any given time, conducting daily operations will become less complex and more efficient as traditional flight planning is enhanced by more detailed information on when which aircraft will be at which position. Thus, pre-flight tasks like crew, fuel and maintenance planning will be executed in a more time- and cost-efficient manner as flight planning input data, based on the negotiated 4DT, will be much more accurate and reliable than they are nowadays.

Figure 23 illustrates a 4DT as it will be followed by an aircraft after the successful implementation of SESAR: The flight starts from the Departure Gate, represented by the left airport symbol. After the Taxi-Out, the aircraft reaches the runway of the departure airport where it releases breaks at the Break Release Point (BRP) and applies take off thrust at 08:55:05 UTC. After take off and climb are conducted, the aircraft overflies the Top of Climb (T/C) at 09:22:21 UTC as well as the Top of Descent (T/D) at 12:01:05 UTC. This phase of flight between the T/C and T/D represents the cruise flight. At 12:26:29 UTC, the aircraft reaches the arrival airport, touching down on the runway at the Touchdown Point (TPT). The last segment of the flight is represented by the Taxi-In, illustrated by the line connecting the TPT with the Arrival Gate. Once there, the aircraft has reached its final parking position. Thus, the 4DT developed by SESAR covers the entire flight from gate to gate.

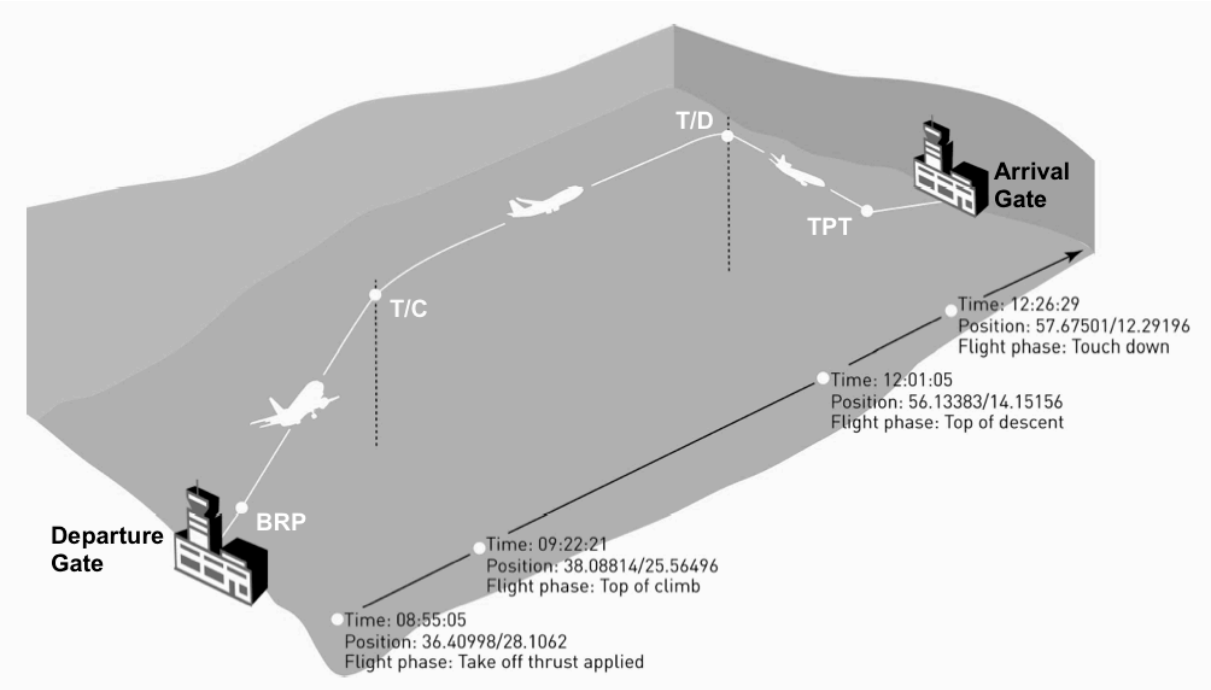


Figure 23: Gate-to-gate 4DT as it will be used in SESAR (times in UTC)[84]

In order to be able to manage, communicate and share the necessary trajectory information in an efficient and secure manner in real time, all authorized stakeholders need to use a common information system which uses, e.g., defined transmission standards and network protocols. Therefore, a System Wide Information Management (SWIM), which represents another SESAR key feature, shall be established. [85][86] Subchapter 3.4.2 serves to describe

[83] Unless no unforeseen events, e.g. sudden temporary airspace restrictions, occur.

[84] SESAR JU /40/, p. 2 (slightly edited)

[85] Cp. Annex 3

[86] SESAR JU /40/, p. 2

SWIM in detail. Moreover, in order to be able to easily share all available trajectory information and agreements, a management tool called *Network Operations Plan* (NOP) is needed. The implementation of a NOP is also a SESAR key feature[87] and is explained in Subchapter 3.4.3.

3.4.2 SYSTEM WIDE INFORMATION MANAGEMENT (SWIM)

The implementation of a System Wide Information Management (SWIM) environment throughout the entire European ATM system shall ensure that all ATM stakeholders can use and share all relevant ATM data collaboratively. The scope of these data covers all information that are relevant for the efficient conduction of ATM. This includes, amongst others, 4DTs, surveillance data, aeronautical information of all types and meteorological data, which are provided by all ATM stakeholders. This also includes service providers, offering f.i. meteorological services (MET), or single vehicles operating on ground of an airport, e.g. passenger buses or fire brigade emergency vehicles.[88]

SWIM is considered as being essential for reaching the SES objectives and SESAR KPA targets.[89] [EUROCONTROL /28/, p. 2] states that "without SWIM[,] SESAR will not work". This is because SWIM is fundamental to the whole SESAR project as Trajectory-Based Operations (TBO) can only take place when all trajectory information is available to all affected stakeholders just in time.[90]

Figure 24 and Figure 25 (p. 28) serve to demonstrate the difference of how relevant ATM information is shared between stakeholders today and how it will be shared in future when SWIM has been established across the entire ATM network.

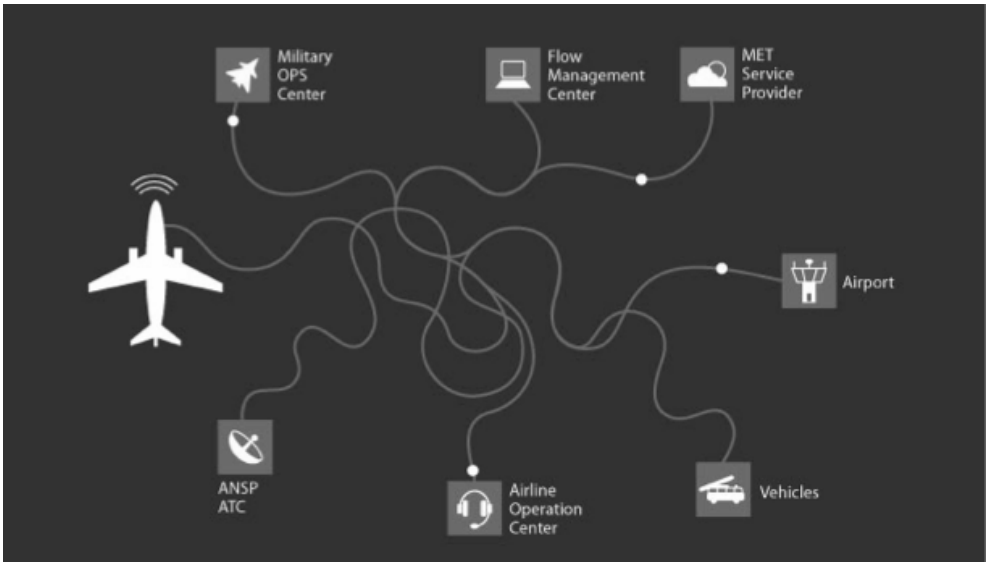


Figure 24: Sharing ATM-related information today (without SWIM)[91]

Figure 24 shows that today, ATM-related information exchange is characterized by many individual-designed point-to-point connections between the individual stakeholders. Custom communication protocols as well as self-contained information systems and applications are used. This results in unnecessary high ATM provision costs as each of these connections

[87] Cp. Annex 3

[88] Figure 24 lists the most important stakeholders of the SWIM network.

[89] Cp. Chapters 3.1 and 3.2

[90] Cp. Subchapter 3.4.1

[91] SESAR JU /43/, p. 73

and protocols has to be "designed, developed, managed and maintained individually and locally".[92] Furthermore, it can be recognized that the way information is provided and shared does not follow system-wide defined specifications. This currently prevents the exchange of available information in real-time in a seamless, secure, reliable and efficient manner amongst all ATM stakeholders.[93]

In contrast, SWIM shall change the way ATM-related information will be exchanged when SESAR is implemented, as depicted in Figure 25. The establishment of SWIM will aim at structuring, harmonizing and standardizing the process of collaborative information exchange throughout the entire ATM system by using a integrated, net-centric and IP-based infrastructure which includes all ATM stakeholders.[94][95] These, together, represent all the nodes of the SWIM network infrastructure.

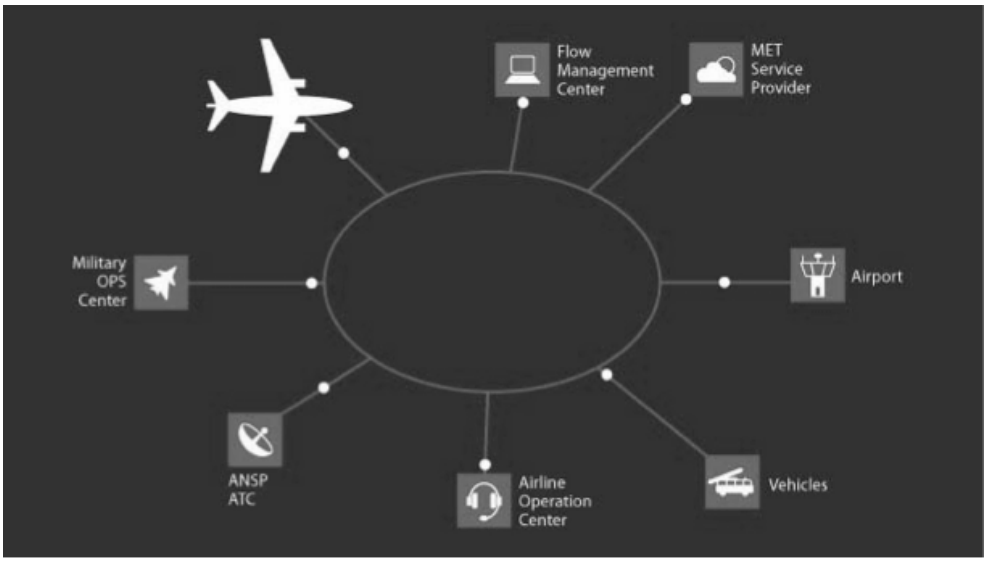


Figure 25: Sharing ATM-related information in the future (with SWIM)[96]

As SESAR emphasizes the concept of Collaborative Decision Making (CDM)[97], all decisions concerning a scheduled flight will be made collaboratively. This means that all SWIM network participants will become both customers and producers of information which they can use and distribute following their individual needs. Decisions felled – resulting from the information available in the network – will be put back into the system so that other participants can rely on the most recent information.[98] In the following, two example will be given:

- The Airport Operations Center (AOC), responsible for allocating gates to all scheduled flights from and to the airport operated, decides – based on an operational requirement of whatever nature suddenly occurring – to change a gate which has been allocate to a certain flight in advance. After having initiated and announced this change, all stakeholders being in need of this bit of information, especially the airline, cockpit crew and ground handler, will be informed about this decision and its outcomes on further operations in real-time.

[92] SESAR JU /42/, p. 1

[93] SESAR JU /42/, p. 1

[94] Boeing /24/, p. 8

[95] EUROCONTROL /28/, p. 2

[96] SESAR JU /43/, p. 73

[97] Cp. Subchapter 3.4.1

[98] EUROCONTROL /28/, p. 2

- Due to a sudden change in weather conditions, e.g. thunderstorm activity, an entire airport has to be closed for both departures and arrivals temporarily. This development has not been anticipated by both the affected flight crews and the OCC flight dispatchers responsible for following their flights since they lacked the necessary meteorological experience. The MET service provider, however, detected the uprising thunderstorm 30 minutes before it led to the airport closure, but was unable to share this important information with all affected ATM stakeholders in time, as they are not only the airlines and their cockpit crews, but also ground handlers, the Airport Operations Center (AOC) and the ATC. Thus, accurate, reliable and timely notification would have given all affected parties enough time to make necessary preparations and decisions, e.g. initiating airborne flight crews to head for alternate airports.

These two examples show that by using SWIM, situational awareness can be maintained and ensured by all ATM stakeholders. This makes flight operations more efficient and increases overall airspace and airport capacity as unforeseen loss of capacity, e.g. resulting from uncertainty of weather events, can be mitigated. Furthermore, safety will also be improved since the possibility of misinterpreting situations will be reduced due to sharing information based on knowledge, experience and skill mutually. This does not only help to avoid fatal and/or expensive misinterpretations, but also to mitigate traffic overloads and subsequent capacity constraints throughout the entire ATM system.[99]

In order to manage all network data efficiently, SWIM defines how ATM-related data will be

- stored,
- checked,
- processed,
- distributed,
- revised, and
- secured

in a way that all relevant information is always available to all authorized stakeholders at the right time and quality.[100] [101] This ensures that real-time Collaborative Decision Making (CDM), based on full knowledge of up-to-date, highly reliable information, can take place between the stakeholders currently in charge of the planning, execution or post-execution of a scheduled flight. SWIM encompasses both ground and airborne stakeholders and, thus, does not only involve ground facilities, but, according to [EUROCONTROL /28/, p. 2], also airborne aircraft which “will become travelling nodes in the network, [being] permanently connected by a new high capacity air/ground data link”.[102]

The efficient management of all SWIM data requires the adoption of the following principles, as outlined by [SESAR JU /42/, p. 2f.]:

- **Separation of information provision and consumption**: As described above, almost every ATM stakeholder is both producer and consumer of information. As the overall amount of network participants is both enormous and likely to alter in terms of amount and nature over the years, it is not productive to irrevocably predefine every participant’s role, responsibilities, dependencies and user privileges in advance. But if every participant is regarded as being both producer and consumer of information ab initio, a separation of information provision and consumption ensures that both minor

[99] SESAR JU /43/, p. 73

[100] SESAR JU /42/, p. 1

[101] EUROCONTROL /28/, p. 13

[102] This new data link technology is called *Controller Pilot Data Link Communication* (CPDLC). According to [EUROCONTROL /28/, p. 14] and [FlitePartners /44/], it particularly serves to reduce air/ground voice communication between ATC and the flight deck by relying on digital asynchronous data transfer via VDL Mode 2/4 and FANS 1/A.

and major changes in the ATM involvement of a individual participant can be managed efficiently and with the least possible influence on other network participants.

- **Loose system coupling**: This principle shall ensure that system components – e.g. applications and hardware – have compatible interfaces as well as protocols and can exchange data in both directions. Therefore, the SWIM system architecture has to be designed in a way that each of the individual components makes as little use of the knowledge of the other components' definitions as possible.
- **Using open standards**: By using open standards which are publicly available – e.g. XML or HTML as document markup language for data integration – the costs for implementing SWIM can be minimized on the one hand whilst, on the other hand, the compatibility, adoptability and perpetual development of system components can be achieved comparatively easily. The use of Commercial Off-The-Shelf products (COTS), as far as reasonably practicable, will also contribute to this. This does not only include applications, but also the connectivity of different system components. For example, the Pan European Network System (PENS) and the internet will be used for Ground/Ground connectivity.[103]
- **Using Service Oriented Architecture (SOA)**: SWIM will use discrete applications, so-called services, as mechanisms for information exchange[104] in order to provide the entire ATM functionality needed by the individual SWIM network participants. These services shall run in an interoperable way and shall be designed flexibly so that they can be adapted to altering processes and requirements at any time. Thus, instead of building one single all-encompassing, hardly adaptable ATM software which is, moreover, cost-expensive in terms of both development and maintenance, many discrete services are combined by using the principle of loose system coupling (as described above). The use of a SOA guarantees that SWIM can be adopted to upcoming needs of change and, hence, meets the SES objectives[105] as it helps to reduce ATM provision costs.

As the implementation of a concept like SWIM across an entire ATM system is a major and most complex task, global interoperability and standardization are irremissible. Since the US American and European ATM systems face equal situations and are currently also subject to major changes, it has been agreed by both the EU and the US American government that the concept of SWIM will also be implemented by NextGen.[106] [107] This guarantees that both the European and US American future ATM systems will be compatible to each another.

As an enormous amount of flight operations must be handled once the SES is established, a so-called Network Operations Plan (NOP) is required in order to ensure that all flights in their combination can be conducted not only according to the SES objectives, but also in a synchronized way. Therefore, the NOP concept, which is another SESAR key feature, is explained in the following Subchapter 3.4.3.

[103] SESAR JU /42/, p. 4

[104] SESAR JU /27/, p. 40

[105] Cp. Chapter 3.1

[106] Enea et al. /41/, p. 3

[107] Cp. Chapter 4.2

3.4.3 NETWORK OPERATIONS PLAN (NOP)

According to Regulation (EU) No. 677/2011, Article 3, a Network Manager (NM), being responsible for the efficient management of the ATM network, shall be established.[108] His/her tasks will, following Article 4 of the same Regulation, encompass to:

- "monitor, report and forecast the performance of the European ATM network based on the agreed [SES] performance targets;
- act as a central unit for air traffic flow management [ATFM] across Europe;
- ensure the European airspace can accommodate the additional capacity needs and seamlessly integrates airports into the network;
- […]
- give Member States and partners access to common resources, such as tools, processes and consistent data to support the cooperative decision-making process at network level;
- support the deployment of technological improvements across the European ATM network".[109]

In order to be able to fulfill these tasks, the NM is – amongst others – responsible for the efficient development, implementation and periodic maintenance of a Network Operations Plan (NOP).

The NOP is a network management tool which both serves to iteratively and collaboratively plan air traffic operations and give a snapshot of the current ATM network status at any point in time. It shall enable the NM to continuously "identify operational constraints, bottlenecks, measures of improvement and solutions for remediation or mitigation".[110] Therefore, all ATM-relevant information must be concentrated coherently in the NOP. This is why all ATM stakeholders which are handling airspace or airport capacity – including air navigation service providers, functional airspace blocks and airport operators – are obliged to "ensure that their operation plans are aligned with the Network Operations Plan".

Once negotiated by the authorized stakeholders, the airspace users' RBTs are also synchronized with the NOP, which supersedes the semi-manual filing of ATC Flight Plans in the future.[111] Thus, by using a NOP, limited airspace and airport infrastructure can be allocated to all RBTs in advance. This raises the overall ATM efficiency as existing capacities can be used optimally while all the stakeholders' needs and requirements are considered. [EUROCONTROL /28/, p. 3] describes vividly how the establishment of a NOP helps to facilitate 4DT operations, both before and while a regarded flight takes place:

> "In the months leading up to the initiation of the flight the iterative planning process refines the trajectories and the available resources and expresses these as the Network Operations Plan (NOP). The NOP is a rolling plan giving a snapshot of the network at any one time. The aim of the NOP is to facilitate the processes needed to reach agreements on demand and capacity. […] Until the aircraft is airborne, available 4D trajectory data retain a level of uncertainty that limits their use for purposes other than planning. Once aircraft are airborne, trajectories attain high precision in the time dimension, and are continuously shared and available via the NOP. Any changes that are required are made through CDM – constraints arising for any reason (other flights, airspace reservations, etc.) are pub-

[108] European Union /45/, p. L 185/4

[109] EUROCONTROL /46/

[110] European Union /45/, p. L 185/6

[111] Cp. Subchapter 3.4.1

lished via the NOP, with the airspace user adjusting the trajectory to comply in a way that best suits the user's operational and business needs."

By taking all ATM stakeholders into consideration, the NOP helps to disclose and reconcile air traffic demand as well as airspace and airport capacities. Moreover, the NOP encompasses a variety of scenarios in order to analyze and cover diverse events likely to occur.[112] Annex V of Regulation (EU) No. 677/2011 gives detailed information on the scope and content of the NOP by providing a template.[113]

[112] EUROCONTROL /28/, p. 9

[113] This template can be found in Annex 4 of this thesis.

4 U.S. AMERICAN ATM INITIATIVE – NEXTGEN

In the following, the U.S. American ATM initiative *NextGen* will be described. After a short description of the objectives and participants (Chapter 4.1) as well as key features (Chapter 4.2) of this project, the European ATM initiative SESAR shall be compared to the U.S. American initiative NextGen (Chapter 5) as to determine commonalities and differences in the concepts of operations.

4.1 NEXTGEN – OBJECTIVES AND PARTICIPANTS

The U.S. American counterpart to the European ATM initiative SESAR is called *Next Generation Air Transportation System* (NextGen). Unlike the European Union (EU) – being an economical as well as political union of states – the USA represents one single country which holds full internal and external sovereignty. As the airspace of a country is internationally considered as the entire aerospace which covers the state's territories[114] [115], the aerospace above the U.S. American territories forms one single U.S. American airspace which is exclusively regulated by the democratically elected government of the USA. Therefore – unlike the European states participating in SESAR under the leadership of the EU – the USA do not need to harmonize and/or re-arrange its airspace as there is no fragmentation due to national borders.[116] [117]

As described in Chapter 1, not only Europe, but also the USA are facing an increasing air traffic volume which will lead to severe airspace and airport constraints. In 2007, the FAA officially estimated that there will be an average annual loss of economic activity of approximately 22 billion $US by 2022 if no ATM modernization measures are be taken.[118] As described in Chapter 1.5, this makes complex ATM optimization and modification measures inevitable as to ensure that air traffic can at least be handled as safely, efficiently and environmentally friendly as it is nowadays.

In order to be able to efficiently realize the organizational, operational and technological requirements resulting from this need, the ATM initiative NextGen was enacted by founding the Joint Planning and Development Office (JPDO) under Public Law 108-176 by President George W. Bush and the U.S. Congress in 2003.[119] Since then, it is the JPDO's responsibility to plan and coordinate the development of NextGen. Therefore, the tasks of the JPDO, which also represents a Public-Private Partnership (PPP), can be compared to that of the SESAR JU.[120]

According to [JPDO /61/], one of the main tasks of the JPDO is to "manage the partnerships designed to bring NextGen online. These partnerships include private-sector organizations, academia, and […] government departments and agencies". The JPDO is officially involved in partnerships with these following entities:

- Department of Transportation (DOT)
- Department of Commerce (DOC)

---

[114] The terms *aerospace* and *airspace* possess two different meanings; whilst *aerospace* is the general term for the earth's atmosphere above a certain terrain, the term *airspace* refers to the portion of the atmosphere controlled by a country above its sovereign territory.

[115] Cp. Giemulla /60/, p. 9ff.

[116] Cp. Chapter 1.5 and Subchapter 3.1.1; Enea et al. /41/, p. 4

[117] This statement refers to the 48 contiguous U.S. American federal states as well as the federal district of Washington, D.C. which are being located in Northern American and does not include the federal states of Alaska and Hawaii as well as the oversea territories in the Caribbean and the Pacific Ocean.

[118] FAA /62/ and Enea /41/, p. 9

[119] JPDO /61/

[120] Cp. Chapter 3.2

- Department of Homeland Security (DHS)
- White House Office of Science and Technology Policy (OSTP)
- Department of Defense (DOD)
- Federal Aviation Administration (FAA)
- Office of the Director of National Intelligence (ODNI)
- National Aeronautics and Space Administration (NASA)

Whilst the JPDO is – together with its partners – responsible for the efficient as well as timely development, revision and implementation of the *NextGen Concept of Operations* [JPDO /64/] and its key features[121] [122], NextGen as a whole – being a political initiative – is officially administrated by the Federal Aviation Administration (FAA) which is the U.S. American aviation authority.

The entire NextGen project, which shall be implemented between 2012 and 2025, mainly aims at increasing airspace as well as airport capacity and flexibility by reducing congestions and avoiding gridlock whilst increasing safety and saving costs throughout the entire U.S. American National Airspace System (NAS). Furthermore, NextGen fosters the reduction of the negative environmental impacts of aviation. All these ambitious goals shall be reached by both increasing airspace as well as airport efficiency and reducing unnecessary detours; this means that once NextGen is implemented, flights between two airports shall be conducted in a more direct, efficient manner as to reduce the time and distance flown in the air.[123]

Therefore, the clearance-based grid-like routing system which is used for operations nowadays will be substituted by individually designed flight routes for every flight which are subject to the principle of Collaborative Decision Making (CDM) between all affected ATM stakeholders.[124] Hence, NextGen will rely on Trajectory-Based Operations (TBO), just like SESAR does.[125] Moreover, existing navigational technologies have to be enhanced and new ones have to be developed and implemented. As stated by [FAA /62/], this mainly encompasses "mov[ing] away from legacy ground based technologies to a new and more dynamic satellite based technology".

All in all, the implementation of NextGen pursues the following objectives, as defined by [JPDO /64/, p. 1-3]:

- **Retain U.S. Leadership in Global Aviation**:
  - Retain role as world leader in aviation
  - Reduce costs of aviation
  - Enable services tailored to traveler and shipper needs
  - Encourage performance-based, harmonized global standards for U.S. products and services
- **Expand Capacity**:
  - Satisfy future growth in demand and operational diversity
  - Reduce transit time and increase predictability
  - Minimize impact of weather and other disruptions

[121] Cp. Chapter 4.2

[122] JPDO /64/, p. ES-1

[123] JPDO /64/, p. ES-1f.

[124] FAA /63/, p. 1ff. and FAA /62/

[125] Cp. Subchapter 3.4.1

- **Ensure Safety**:
  - Maintain aviation's record as the safest mode of transportation
  - Improve level of safety of U.S. air transportation system
  - Increase level of safety of worldwide air transportation system
- **Secure the Nation**:
  - Mitigate new and varied threats
  - Ensure security efficiently serves demand
  - Tailor strategies to threats, balancing costs and privacy issues
  - Ensure traveler and shipper confidence in system security
- **Ensure National Defense**:
  - Provide for common defense while minimizing civilian constraints
  - Coordinate a national response to threats
  - Ensure global access to civilian airspace
- **Protect the Environment**:
  - Reduce noise, emissions, and fuel consumption
  - Balance aviation's environmental impacts with other social objectives

These objectives, having been defined by [JPDO /65/, p. 7ff.] by publishing the *Next Generation Air Transportation System (NGATS) Integrated Plan* in 2004, are very similar to the Key Performance Areas (KPA) fostered by SESAR, except for the strong focus on national defense and homeland security.[126] [127] Moreover, the NextGen objectives have not been defined quantitatively (e.g.: reduce noise, emissions, and fuel consumption by 30% within 10 years), but only qualitatively (e.g.: reduce noise, emissions, and fuel consumption).

This means that, unlike when the SESAR objectives were specified, no measurable *Key Performance Indicators* (KPI) have been defined in advance, underlining the JPDO's intent to continuously meet the future requirements resulting from the actual – not the estimated – development of the global aviation market; however, the qualitative definition of NextGen objectives is subject to the development of the aviation market and follows the three following higher-level goals, as stated by [NCOIC /66/, p. 3]:

- "Meet the diverse operational objectives of all airspace users and accommodate a broader range of aircraft capabilities and performance characteristics
- Meet the needs of flight operators and other NextGen stakeholders for access, efficiency, and predictability in executing their operations and missions
- Be fundamentally safe, secure, of sufficient capacity, environmentally acceptable, and affordable for both flight operators and service providers".

As to be aware of how the NextGen objectives are met and how this, in return, influences the U.S. American ATM, the website [FAA /67/] continuously monitors and lists detailed NextGen performance snapshots.

[126] Cp. Chapter 3.2

[127] However, even if this cannot directly be derived from the objectives defined within the SESAR initiative, the SESAR Concept of Operations also considers the military airspace users as ATM stakeholders and targets the integration of military operations (= missions) into the ATM environment.

According to the definitions provided in [JPDO /64/, p. ES-4f.], the successful implementation of the NextGen initiative comprises the following ATM stakeholders[128]:

- **Airport Communities**: "Cities and towns located in the vicinity of airports that have a vested interest in and are affected by the operation of the airport."
- **Airport Operators**: "[Airport operators are] responsible for enabling passenger, flight, and cargo operations conducted within an airport with consideration for safety, efficiency, resource limitations, and local environmental issues."
- **Airport Tenants**: "[Airport tenants] are involved in airport operations, such as fueling, maintenance or catering services."
- **Air Navigation Service Provider (ANSP)**: "[ANSPs are] engaged in providing ATM and Air Traffic Control (ATC) services for flight operators for the purpose of safe and efficient flight operations. ATM responsibilities include Communications, Navigation, and Surveillance (CNS). They also include ATM facility planning, investment, and implementation; procedure development and training, and ongoing system operation and maintenance of seamless CNS/ATM services."
- **[Airspace] Users**: "[This includes] civil, government, and military [airspace users], using NAS services."
- **Flight Operators**: "[Flight Operators are] responsible for planning and operating a flight within the NAS. This includes flight crews, Flight Operations Centers (FOC), private, business, scheduled air transport, government, and military operators."
- **Manufacturers**: "Manufacturers produce items that support flight operations to include: airframes, aircraft engines, avionics, aircraft systems and parts, airport and ATM equipment and infrastructure, Decision Support Systems (DSS), and other components."
- **Resource Owners**: "[Resource owners are] responsible for making investment decisions related to development and implementation."
- **Regulatory Authorities**: "[Regulatory authorities are] responsible for governing aspects of the overall performance of the aviation industry including safety, security, standardization, certification, environmental effects, and international trade."
- **Researchers**: "[Researchers are] engaged in conducting Research and Development (R&D) activities that support the evolution of the air transportation system, including academia and government organizations."
- **Security and Defense Providers**: "[Security and Defense Providers are] responsible for national security and homeland defense, law enforcement, and information security, as well as the physical and operational security of the NAS."
- **Weather Service Providers**: "[Weather Service Providers are] engaged in the provision of aviation weather products."

It becomes apparent that NextGen involves more different stakeholders than SESAR and even accounts for stakeholders which are only indirectly affected by the actual conduction of ATM, e.g. airport communities, researchers and resource owners.[129] Moreover, Flight Operators are listed separately and are not necessarily considered as being airspace users. Thus,

[128] The statements behind the colons adopt the official definitions of the stakeholders' functions as given in [JPDO /64/, p. ES-4f.]

[129] Cp. Chapter 3.2

this classification of stakeholders also considers the fact that flight operation services may not be conducted by an airline itself, but may be outsourced.

All in all, this classification allows all affected stakeholders to actively participate in the aviation business and its operations.[130]

4.2 NEXTGEN – PROJECT PHASES AND KEY FEATURES

The implementation of NextGen – being currently ongoing – consists of the three epochs: *Research & Development* (Epoch 1: 2006-2015), *Deployment* (Epoch 2: 2012-2019) and *Integration for Operational Usage* (Epoch 3: 2018-2025).[131]

Once finished, the current U.S. American ATM will have altered significantly. This is mainly due to the fact that NextGen fosters the transformations from clearance-based operations to Trajectory-Based Operations (TBO) as well as from rules-based operations to Performance-Based Operations (PBO).[132] Moreover, [JPDO /64/, p. ES-5] states that NextGen will change the way aircraft separation is guaranteed as there will be a "transition of separation responsibility from the controller to the flight crew, in certain areas, [which] allows controllers to focus on overall flow instead of individual flight management".

Once fully conducted, the combination of all these transformations will enhance the entire ATM system in a way as to improve airspace as well as airport capacity, air traffic flow management and ATM efficiency. Furthermore, NextGen will ensure not only safe, but secure air traffic operations as well as a sustainable and efficient growth of the U.S. American aviation market in the long term.

In order to meet the objectives described in Chapter 4.1, the implementation of the following key features – officially referred to as *concepts* by both the JPDO and the FAA – is required[133]:

- **Net-Centric Operations**: "Through network-enabled information access, information is available, securable, and usable in real-time for Communities of Interest (COI) and air transportation domains. This greater accessibility enables better distribution of information and improves the speed, efficiency, and quality of this process. Information can be automatically provided to users with a known need and be available to users not previously identified as new needs arise. Information access improves operational decision making, enabling system operators the use of risk management practices to enhance safety. Cooperative surveillance for civil aircraft operations, where aircraft constantly transmit their position, is used with a separate sensor-based, non-cooperative surveillance system as part of an overall integrated federal surveillance approach."
- **Performance-Based Operations and Services**: "Performance-based operations provide a foundational transformation of NextGen. Regulations and procedural requirements are described in performance terms rather than in terms of specific technology or equipment. Minimum performance levels are expected to be required to maximize capacity in congested airspace during specific periods of time. Service providers can use service tiers to create guarantees for different performance levels so that users can make the appropriate tradeoffs between investments and level of service desired to meet their needs. A benefit of performance-based operations and ser-

[130] JPDO /64/, p. 1-3

[131] Sudarshan /73/

[132] JPDO /64/, p. ES-5

[133] The statements behind the colons adopt the official definitions of the NextGen concepts as given in [JPDO /64/, p. 1-10f.]

vices is that service providers can define capability improvements in terms of users' existing equipage, thus potentially maximizing the value of the service providers' and users' investments."

- **Weather Assimilated into Decision Making**: "By assimilating weather into decision making, weather information becomes an enabler for optimizing NextGen operations. Directly applying both probabilistic and observed weather information to ATM decision tools increases the effective use of weather information and minimizes the adverse effects of weather on operation."
- **Layered, Adaptive Security**: "Layered, adaptive security includes a security system that consists of "layers of defense" (including techniques, tools, sensors, processes, information, and a robust Integrated Risk Management [IRM] system). This type of security system helps reduce the overall risk of a threat reaching its objective while minimally affecting efficient operations. Layered security is additive; failures in any one component should not have a catastrophic effect on other components. For that reason, the system is well suited to handle attacks and incidents, intrusions or attacks with minimal overall disruption. Layered, adaptive security adjusts the deployment of security assets in response to the changing IRM profile of risks; responses to anomalies and incidents are proportional to the assessed risk."
- **Positioning, Navigation and Timing Services (PNT)**: "PNT services are near ubiquitous, in accordance with demand and safety considerations, to enable reliable aircraft operations in nearly all conditions. Rather than being driven by the geographic location of a ground-based Navigational Aid (NAVAID), NextGen PNT services allow operators to define the desired flight path based on their own objectives."
- **Trajectory-Based Operations (TBO)**: "The basis for TBO is knowing each aircraft's expected flight profile and time information (such as departure and arrival times) beforehand. The specificity of 4DT matches the mode of operations and the requirements of the airspace in which an aircraft operates. A major benefit of 4DT is that it enables service providers and operators to assess the effects of proposed trajectories and resource allocation plans, allowing service providers and operators to understand the implications of demand and identify where constraints need further mitigation."
- **Equivalent Visual Operations (EVO)**: "Improved real-time information allows aircraft to conduct operations in less than direct visual observation. For aircraft, this capability, in combination with PNT, enables increased accessibility, both on the airport surface and during arrival and departure operations. This capability also enables those providing services at airports (such as ATM or other ramp services) to provide services in all visibility conditions, leading to more predictable and efficient operations."
- **High-Density Arrival/Departure Operations**: "An even greater need exists to achieve peak throughput performance at the busiest airports, in the most crowded airspace, during peak times. New procedures to improve airport surface movements, reduce spacing and separation requirements, and better manage overall flows in and out of busy metropolitan airspace, maximize the use of the highest-demand airports. Airport terminals also optimize efficiency of egress and ingress, matching passenger and cargo flow to airside throughput while maintaining safety and security levels."

Figure 26 (p. 39) schematically illustrates how these NextGen key features defined above will work together in 2025 when the implementation of NextGen is finished and all key features are integrated. Both public and private stakeholders are involved, as well as the ICAO which is responsible for global harmonization of ATM systems. Moreover, civil and military airspace users are considered. The lower part of Figure 26 serves to specify different kinds of information needed for the efficient conduction of ATM according to the NextGen objectives spec-

ified in Chapter 4.1. Additionally, the partners involved with the JPDO are also shown at the upper part of Figure 26.[134]

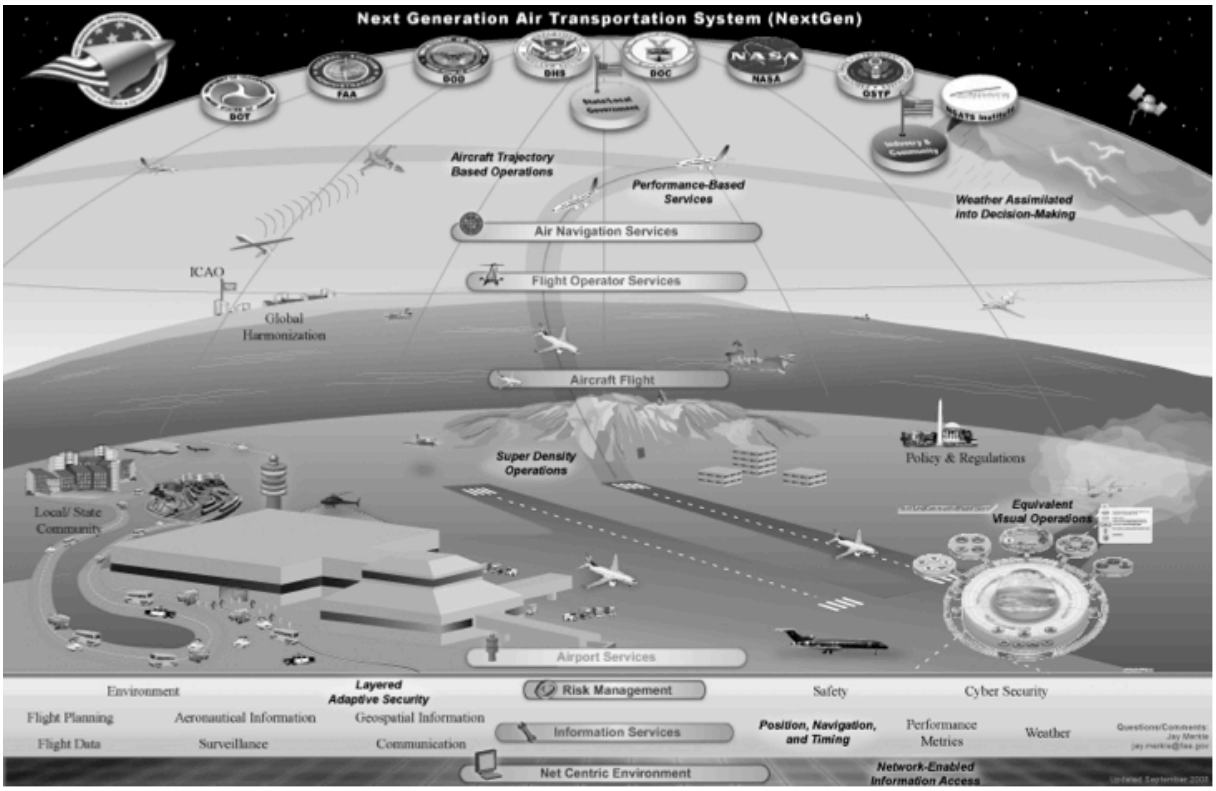


Figure 26: NextGen key features, JPDO partnerships and NextGen stakeholders[135]

According to [JPDO /64/, 1-13f.], the implementation of these key features is essential to the success of NextGen as they will provide the NextGen ATM system with nine essential *capabilities*, which are similar to the *Key Performance Areas* (KPA) specified for SESAR[136]. Once established, these capabilities will ensure a safe, efficient, flexible, sustainable and secure conduction of future air traffic operations and consider the needs and requirements of all stakeholders by fostering Collaborative Decision Making (CDM) throughout the entire ATM environment. The nine NextGen capabilities specified by [JPDO /64/] are described in the following:

- **Collaborative Capacity Management (CM)**: Implementing this capability will provide the possibility that National Airspace System (NAS) stakeholders jointly adjust the forecasted demand for air traffic operations with the existing ATM resources in a dynamical way. These resources comprise not only available airspace and airport capacities, but also other ATM system resources like personnel for operational support, administration and maintenance of relevant ATM components. Thus, NAS resources are allocated by means of proactive and collaborative strategic planning and use Decision Support Systems (DSS) as to automate this process.

  As shown in Figure 27 (p. 40), CM consists of two components, the short and long term capacity management. The *Short Term Capacity Management* component is used for the reallocation of NAS assets and the use of procedures in order to maximize NAS utilization according to the forecasted demand. In contrast, the *Long Term Capacity Planning* component shall ensure that major changes to the NAS (e.g. air-

[134] Cp. Chapter 4.1

[135] JPDO /64/, p. 1-12

[136] Cp. Chapter 3.2

space design, significant airport as well as infrastructure improvements, and the establishment of new operational procedures) may be planned collaboratively.

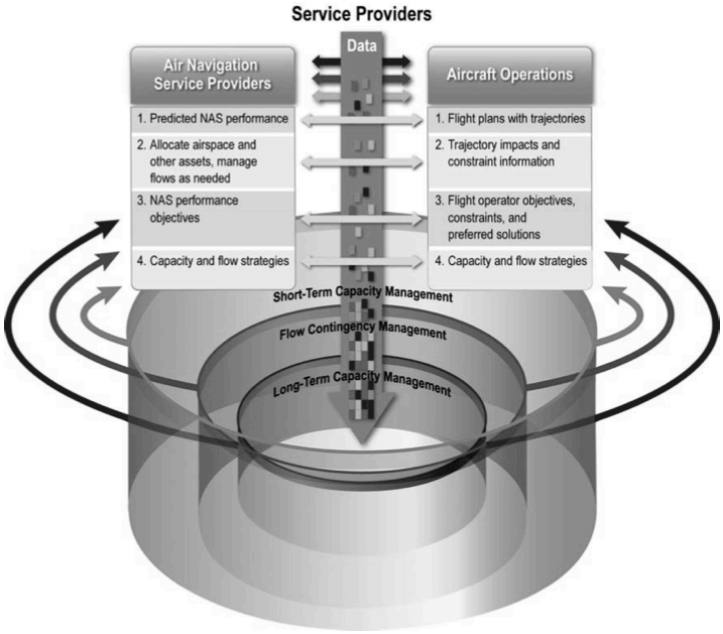


Figure 27: NextGen - Capacity Management (CM)[137]

The main principle of CM is to allocate existing NAS resources in a way to meet the overall NextGen objectives and not the operational and/or business needs of single NAS stakeholders.[138]

- **Collaborative Flow Contingency Management (FCM)**: FCM will provide the NAS stakeholders to efficiently perform Air Traffic Flow Management (ATFM) collaboratively as (near)-real-time decision making will ensure an optimal, synchronized and safe allocation of air traffic flows to existing airspace capacities. This shall prevent ATM-related delays and resulting costs by identifying and resolving ATFM-related disruptions, e.g. by considering constrained or blocked airspaces.

  CM and FCM are intermeshed in a way that FCM takes over where demand-driven incapacities may not be addressed by CM. Thus, FCM is used for conflict-managing between different stakeholder's requirements and needs. Conflict-solving is done by regarding not only the conflict between multiple stakeholders, but by analyzing all available NAS resources and recommending alternatives which suit the stakeholders' objective the most.[139]

- **Efficient Trajectory Management (TM)**: If an ATFM incapacity occurs shortly before or during the conduction of a flight, TM enables the Air Navigation Service Provider (ANSP) to efficiently re-assign trajectories to the affected airspace users by negotiating and adjusting their 4DTs individually with the support of corresponding TM-tools. As this is done proactively throughout the entire ATM system, TM helps to minimize the complexity and frequency of short-term conflicts and reduces ATM-related costs. Moreover, TM and *Separation Management* (SM)[140] are interlinked closely. This ensures that even if trajectories have to be altered on short notice, separation between

[137] JPDO /64/, p. 2-10

[138] JPDO /64/, p. 2-10f.

[139] JPDO /64/, p. 2-12f.

[140] see further below

nearby aircraft is accounted for and maintained. Thus, TM is a tool which helps to mitigate the negative outcomes of short-term conflicts and shall enable the ANSP to resolve these conflicts in the most efficient manner while ensuring safety at any time.[141]

- **Flexible Separation Management (SM)**: Establishing and maintaining separation is essential to the safe and efficient conduction of operations; on the one hand, separation guarantees that collisions are avoided. On the other hand, separation represents a limiting factor for both airspace and airport capacity. Thus, safety and efficiency have to be balanced when it comes to SM.

  In NextGen, SM provides the possibility not only to separate aircraft from each other, but also aircraft from vehicles, protected or blocked airspaces, terrain, obstructions and severe weather, e.g. thunderstorms. Moreover, SM is a real time NextGen process which is implemented to predict and resolve upcoming conflicts, e.g. by recommending possible solutions regarding aircraft course, altitude and speed. This helps to both ensure the conduction of flights according to safe separation minimums and meet capacity demand by using automated DSS. Thus, SM supports the ANSP which is responsible for separation.[142] As stated above, SM is intermeshed with TM in a way that Trajectory-Based Operations (TBO) can be conducted safely and efficiently, even if short-term conflicts occur. Therefore, algorithms are used to identify solutions to conflicts at least several minutes before minimum separation would be undershot, following the ICAO SARPs concerning the *Rules of the Air* provided in [ICAO /69/].[143]

- **Flexible Airport Facility and Ramp Operations**: This capability ensures that available airport facilities and assets are used in a way as to realize an acceptable Level of Service (LoS), even during high-density operations. Therefore, assigned airport facilities and ramp assets may be flexibly reallocated between stakeholders by using DSS. As this capability considers all existing airside, landside and terminal airport infrastructure and services and not only the ones preferred by a single stakeholder, airport capacity can be adjusted optimally to the stakeholders' demand.[144]

- **Integrated NextGen Information**: This capability, which is similar to SWIM – as described in Chapter 3.4.2 – shall provide authorized ATM stakeholders with "timely, accurate, and actionable information (e.g., weather, surveillance, aeronautical information, operational and planning information, and position, navigation and timing information)" in a Service-Oriented Architecture (SOA)[145] environment.[146] This contributes to the conduction of net-centric operations, as specified further above in the Chapter and shall enable all stakeholders to improve situational awareness whilst reducing the time needed for the exchange of reliable, up-to-date information. Thus, the amount of different types of interfaces and systems will be reduced as harmonization will ensure interoperability and simplify collaboration.[147]

- **Air Transportation Security**: NextGen specifies securing the NAS as one of its main objectives.[148] Therefore, this capability shall provide a layered, adaptive security management system which "permits the use of increased variability in security sys-

[141] JPDO /64/, p. 2-15

[142] When possible, the ANSP may delegate this responsibility to cockpit crews which are flying self-separation-capable aircraft.

[143] JPDO /64/, p. 2-15f.

[144] JPDO /64/, p. 3-2

[145] For further explanation, cp. Definitions and Subchapter 3.4.2

[146] JPDO /64/, p. 1-13 and NCOIC /66/, p. 9

[147] JPDO /64/, p. 4-7

[148] cp. Chapter 4.1

tem operations that creates more uncertainty for an adversary" and allows for the effective defeat of threats.[149] Moreover, the adaptivity ensures that various threats can be defeated synchronously as the security system is able to adapt its system resources and processes to the risk level of given threats and may not be annulled easily by a combination of various attacks.[150]

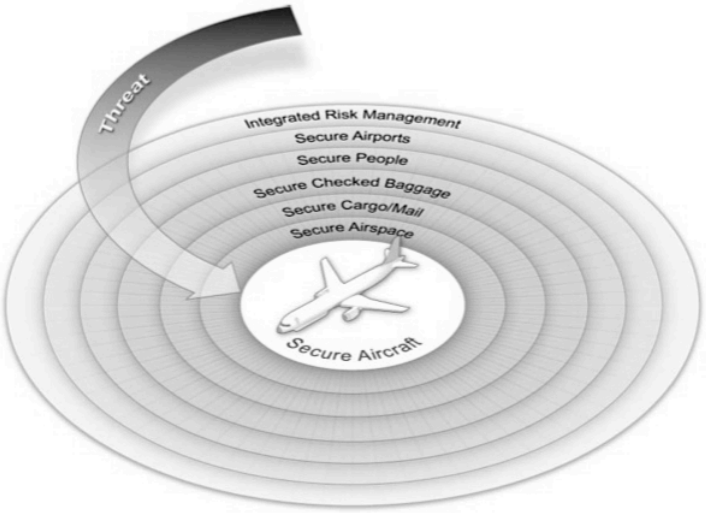


Figure 28: NextGen - security system concept[151]

Figure 28 shows the elements which are being addressed by the NextGen security system. In order to achieve the highest degree of system security and considering the limitedness of both governmental and private assets available for the mitigation of threats, [JPDO /64/, p. 6-2] states that it is essential that mitigation measures are "developed based on threat and vulnerability as well as the potential consequences to individuals, critical national assets, significant events/activities, and the economy".

- **Improved Environmental Performance**: Once implemented, this capability provides the possibility to efficiently identify and address environmental impacts in the areas of noise, emissions, water quality and greenhouse gas emissions caused by air traffic. This shall be reached by a combination of tools, technologies, operational policies and procedures being compliant with both U.S. American and international regulations.[152]

- **Improved Safety Operations**: NextGen fosters the concept of Safety Management, based on the framework provided by the ICAO *Safety Management Manual* [ICAO /71/]. Thus, integrated safety management shall ensure safe operations between all ATM stakeholders, as they are not only aircraft, but e.g. also vehicles operated by airport tenants.[153] Safety Management proactively helps to avoid both accidents and incidents as safety-relevant processes are steadily monitored. Thus, risks and hazards can be identified and mitigated proactively. Moreover, the reports of past accidents and incidents are analyzed reactively as to ensure that the failures which caused the occurrence may not happen again. Both these proactive and reactive measures result in an increase in the overall level of safety, which, in direct return,

[149] JPDO /64/, p. 6-1

[150] JPDO /64/, p. 1-13

[151] JPDO /64/, p. 6-2

[152] JPDO /64/, p. 7-1

[153] JPDO /64/, p. 8-1ff.

does not only prevent personal damage but also reduces costs for compensation when it comes to loss of life or damage to material goods.[154]

In order to ensure that all stakeholders benefit from the other stakeholders' safety-relevant experiences, NextGen integrates an ATM system-wide Safety Management which provides the possibility to collaboratively share information concerning not only the identification and analysis, but also the assurance, promotion and mitigation of risks and hazards.[155]

Based on the NextGen *Concept of Operations* [JPDO /64/], this Chapter summarized the NextGen project phases as well as key features and described the capabilities which shall be operationally used once NextGen is fully implemented. The following Chapter 5 serves to compare the concepts of operations of SESAR and NextGen in order to identify commonalities and differences.

[154] airsight /72/

[155] JPDO /64/, p. 8-1ff.

5 GENERAL COMPARISON OF THE SESAR AND NEXTGEN CONCEPTS OF OPERATIONS

In this Chapter, the concepts of operations of SESAR and NextGen are compared against each other in order to be able to identify commonalities and differences in their key features. Therefore, Table 3 compares the both ATM initiatives by means of a high level analysis and serves to summarize the statements made in the previous Chapters 3, 4.1 and 4.2.

	SESAR	**NextGen**
Approach	Sub-regional	National
Objectives	(Quantitatively defined) • Threefold increase in capacity • Reduce ATM cost by half • Reduce environmental impact by 10% • Increase safety by a factor of 3 by 2020 and 10 in the long term	(Qualitatively defined) • Retain U.S. leadership in aviation • Expand capacity • Protect environment • Ensure safety • Ensure U.S. national defense
Governance	Public-Private Partnership	Public-Private Partnership
Planning	3 Phases: Definition (2005 to 2008); Development (2008 to 2015); Deployment (2014 to 2020)	3 Epochs: Epoch 1 (2006 to 2015); Epoch 2 (2012 to 2019); Epoch 3 (2018 to 2025)
Cost	approx. 1,560 Million EUR (= approx. 2,143 Million $US)	approx. 1,191 Million $US (= approx. 867 Million EUR)
Compatibility	Consistent with ICAO ATM concept	Consistent with ICAO ATM concept
Technologies	• Digital communications & surveillance • ADS-B IN & OUT • Net-centric infrastructure • GNSS • Automation	• Digital communications & surveillance • ADS-B IN & OUT • Net-centric infrastructure • GNSS • Automation
Operations	• 4DT management • CDM • SWIM	• 4DT management • CDM • SWIM

Table 3: High level comparative analysis of SESAR and NextGen[156]

Table 3 lists the estimated cost for both initiatives, as of March 2012.[157] As it can be recognized by considering recent currency exchange rates, SESAR is approx. 1.8-fold as expensive as NextGen[158], which can mainly be ascribed to the necessary creation of European FABs, as described in Subchapter 3.1.1.

Although SESAR will be fully implemented five years earlier than NextGen, both initiatives and the concepts integrated within are pretty much the same. According to [NCOIC /66/, p. iii], both foster “an integrated Air Traffic Management System wherein automated tools, data

[156] Author’s own illustration; based on Sudarshan /73/

[157] Sudarshan /74/

[158] Currency exchange rate, as of December 15, 2013: 1 EUR = 1.37 $US

network infrastructures, improved surveillance capabilities, weather capabilities, and advanced information services team together to address concerns caused by increased traffic […] [as to] enable highly efficient, effective, and safe ATM operation […] [by relying on] continuous and robust data communications between all assets within the system".

This statement implicates that 4DT management, CDM and SWIM are essential for both SESAR and NextGen. As SESAR will be implemented earlier and both the European Union and the government of the USA officially agreed upon ATM harmonization under the aegis of ICAO[159], SESAR has a leading role when it comes to the specification, development and deployment of these technologies.[160] Therefore, [EUROCONTROL /33/] states that NextGen "is being coordinated with the ATM Master Plan in Europe in order to assure alignment where necessary and joint inputs to ICAO".

The following Subchapters 5.1.1 to 5.1.3 serve to highlight how SESAR and NextGen differ in the implementation and operational usage of SWIM, CDM and 4DTs. This analysis is mainly based on the research papers published by [Enea et al. /41/] and [NCOIC /66/] and represents a fundament for identifying how both SESAR and NextGen will influence the OCCs' role as well as OCC-cockpit crew workflows.[161]

5.1.1 IMPLEMENTATION AND OPERATIONAL USAGE OF SWIM

SWIM is a fundamental, first-level technology which has to be provided before other second-level technologies – such as the SESAR and NextGen key features CDM and 4DT management – can be implemented.[162] This is due to the fact that SWIM is used to share all kinds of information which are necessary for the conduction of operations according to meet both the SESAR and NextGen objectives, as they included information on trajectories, surveillance data, aeronautical information and meteorological data.[163][164]

As to ensure that those key features can be used in a way that decisions affecting the ATM stakeholders can be made collaboratively, all SESAR and NextGen stakeholders have to be provided with all necessary data just-in-time. Hence – albeit not being explicitly mentioned as a NextGen key feature in the NextGen ConOps [JPDO /64/] – the SWIM technology, which is also fostered by SESAR[165] and is internationally accepted as being an ICAO standard technology for ATM systems[166], will also be integrated into the NextGen environment, as stated by both [NCOIC /66/, p. 4] and [ICAO /70/, p. 19].

This is essential as it guarantees that SWIM will not be solely integrated into both ATM systems separately, but that SESAR and NextGen will be interoperable in a manner as to ensure that both European and U.S. American ATM stakeholders can rely on the same information and ATM services when it comes to transatlantic air traffic operations.[167] As a result, the handling and conduction of such operations will become easier as well as more reliable, affordable and projectable for all affected ATM stakeholders. This is due to the fact that they benefit from the net-centric, system-wide information-sharing fostered by both initiatives

[159] SESAR JU /27/, p. 14ff. and ICAO /70/, p. 4ff.

[160] NCOIC /66/, p. 21

[161] Cp. Chapter 7

[162] Cp. Chapters 3.4 and 4.2

[163] Cp. Chapters 3.2 and 4.1

[164] NCOIC /66/, p. 8

[165] Cp. Subchapter 3.4.2

[166] Cp. ICAO /68/, p. 2-16

[167] NCOIC /66/, p. 5

which makes operations become more efficient. Thus, both aviation markets are positively affected as synergic effects will be created.

However, in order to ensure interoperability, SWIM data formats and user rights have to be standardized and normalized. Therefore, both SESAR and NextGen foster the establishment of a *reference model* for ATM data and the provision of information services in a Service-Oriented Architecture (SOA).[168] This shall enable the stakeholders of SESAR and NextGen to exchange reliable, high-quality ATM data in (near)-real-time and may be one significant step towards the implementation of a globally accepted ATM data reference model. So far, such a model – called *Aeronautical Information Exchange Model* (AIXM) – does only exist for the digital exchange and distribution of Aeronautical Information Services (AIS), especially NOTAMs.[169]

As to lay down a detailed concept for the implementation of SWIM and to identified necessary technologies, the EU initiated a research project called *SWIM-SUIT* in 2007.[170] It aimed at specifying requirements for SWIM as well as developing a SWIM prototype which should serve as a test platform for the evaluation of SWIM technologies as to validate a seamless exchange of data between SESAR and NextGen.[171] Whereas the validation showed that SWIM works within Europe, the differences in Air-to-Ground (A/G) connectivity between SESAR and NextGen, e.g. by means of *Controller Cockpit Data Link Communications* (CPDLC), have not been addressed within the SWIM-SUIT project; yet, SESAR and NextGen differ in the way aircraft access SWIM; whilst SESAR directly includes A/G connectivity within its SWIM concept, NextGen fosters a so-called *Aircraft Access to SWIM* (AAtS) as to ensure aircraft access to the ground-based SWIM architecture. Therefore, it has to be analyzed whether SWIM interoperability is ensured.

Furthermore, it has to be considered that both initiatives – especially the U.S. American one – have a strong focus on securing and defending their future ATM environment and the data processed within.[172] Therefore, the access to and the operational exchange of relevant ATM information will be subject to strict regulations and intelligence-led policing as well as counter-terrorism. According to [NCOIC /66/, p. 8], this will lead to situations where “not all users will have permission to access all data within a domain because of operational, commercial or security reasons”. Furthermore, both SESAR and NextGen represent an environment where all stakeholders are – at least potentially – able to access all the other stakeholders’ data; therefore, the legal problem of defining who is possessor and who is owner of certain pieces of information has to be solved in general before SWIM may be used for operations.[173]

5.1.2 IMPLEMENTATION AND OPERATIONAL USAGE OF CDM

In order to make ATM-relevant decisions collaboratively, allow for 4DT management and improve dynamic Demand and Capacity Balancing (DCB), both SESAR and NextGen foster the implementation of Collaborative Decision Making (CDM).[174] As described in the previous Subchapter 5.1.1, SWIM must be implemented in order to be able to provide CDM. This is due to the fact that SWIM represents the infrastructure which is used to share relevant information and decisions amongst ATM stakeholders.

---

[168] Cp. Subchapter 3.4.2 and Chapter 4.2

[169] NCOIC /66/, p. 18

[170] Jeppesen /84/, p. 16

[171] SWIM-SUIT /83/, p. 2f.

[172] Cp. Chapter 4.2

[173] NCOIC /66/, p. 21

[174] Cp. Subchapter 3.4.3

That, in direct return, means that CDM strongly relies upon the reliability and data integrity of SWIM, as explained by [NCOIC /66/, p. 18]. When it comes to irregularities – e.g. a system breakdown caused by a blackout, malfunctioning software or wrong database entries – CDM may no longer be conducted in a safe, secure and/or efficient manner.[175] In the worst case, missing or wrong information may not only lead to disruptions and inefficiencies, but may also cause accidents and incidents if it comes to miscalculation or wrong interpretation of 4DTs.[176] Therefore, adequate measures for each imaginable critical scenario have to be defined in advance as to ensure the operational safety, security and efficiency of ATM at any point in time.

Moreover, CDM has to be standardized and harmonized as to ensure that transatlantic operations, using both the European and the U.S. American ATM system, can be covered. This comprises not only the specification of SWIM reference data models and Decision Support Tools (DST), but also the definition of common CDM operational procedures, priorities, objectives and powers of decision. Therefore, a common Network Operations Plan (NOP), as described in Subchapter 3.4.3, is essential.

Whereas the European Union explicitly fosters the implementation of such a NOP into SESAR and specifies how this shall be achieved, NextGen does not. [177] [178] This makes further harmonization between SESAR and NextGen necessary. Yet, as SESAR shall be implemented five years earlier than NextGen, [NCOIC /66/, p. 21] reasons that "all airlines with European routes will be required to harmonize with EUROCONTROL solutions early, as each entity seeks long term interoperability solutions". As the stakeholders affected by both SESAR and NextGen will be – both from a technological and financial point of view – unwilling and/or unable to implement two new CDM standards and adherent technologies within a 5-year-period, the FAA is likely to either adjust their CDM standards to the ones already existing in the EU or to fully adopt them.

5.1.3 IMPLEMENTATION AND OPERATIONAL USAGE OF 4DTS

SESAR and NextGen represent a paradigm shift as they both focus Trajectory-Based Operations (TBO) instead of clearance-based operations.[179] This means that a flight will no longer be filed and cleared according to waypoints specified in an ATC flight plan, but according to an exact 4-Dimensional Trajectory (4DT) which has been agreed upon between the affected airspace user (airline) and the other ATM stakeholders before the actual flight takes place. Once negotiated by means of CDM[180], this 4DT will become binding and is called *Reference Business Trajectory* (RBT), describing the spatial 3D position of the aircraft at any given point in time during the entire flight. According to [Enea et al. /41/, p. 1], the usage of 4DTs "will satisfy many of the airline[s'] preferences, with particular attention to fuel consumption reduction". Moreover, the general predictability, safety and efficiency of operations will be increased as 4DT management aims at avoiding airspace and airport congestions while guaranteeing safe separation minimums at every point in time.[181]

---

[175] NCOIC /66/, p. 18f.

[176] This will be explained in detail in the following Subchapter 5.1.3.

[177] Cp. Subchapter 3.4.3

[178] NCOIC /66/, p. 7

[179] Cp. Subchapter 3.4.1 and Chapter 4.2

[180] In order to able to use 4DTs, the previous implementation of SWIM and CDM is mandatory.

[181] Cp. Subchapters 3.1.2 and 3.4.1

Following the analysis of [Enea et al. /41/], it can be summarized that SESAR and NextGen are basically equal in terms of their concepts of 4DT management.[182] Therefore, both initiatives rely upon the following technologies, as they are:

- **Advanced Flight Management System (FMS) Capabilities**: As a trajectory has to be calculated and managed by the FMS of an aircraft, current FMS have to be adapted accordingly. This means that they must be capable of processing complex 4DTs for both short and long haul flights. As one dimension of a 4DT is time, it has also to be ensured that the FMS will be able to compare the *Target Time of Arrival* (TTA) at a random waypoint against the *Actual Time of Arrival* (ATA) at this waypoint. As it is – both for operational and technological reasons – not realistic that each waypoint will be overflown exactly at a pre-defined TTA, certain tolerances have to be accepted and taken into account. Therefore, the term *Controlled Time of Arrival* (CTA) has been established. It represents, based on the TTA, a certain time tolerance within which the aircraft may cross a specific waypoint. The FMS of an aircraft operated in either the SESAR or NextGen environment has to be capable of managing and observing these time constrains with a certain accuracy. This accuracy is, amongst others, influenced by the current wind, speed as well as altitude constrains and the configuration of the aircraft.[183] [184]

- **Data Communication:** In order to be able to conduct TBO, data communication between ATC and the cockpit crew has to be established as voice communication will not be sufficient for the amount and complexity of the transmitted data. This is due to the fact that navigation will no longer take place according to ATC clearances for certain headings, altitudes and speeds, but according to trajectories; these cannot be transmitted safely and efficiently by means of voice communication as there might be misinterpretations and misspellings. Additionally, the workload for both pilots and air traffic controllers would increase disproportionally as it would take much longer to communicate requests and clearances.

  Therefore, standardized requirements for an advanced data communication service named *4DTRAD* have been jointly developed by the U.S. American Radio Technical Commission for Aeronautics (RTCA) and the European Organisation for Civil Aviation Equipment (EUROCAE). According to [Enea et al. /41/, p. 4], 4DTRAD will serve to negotiate and synchronize 4DT data between ground and airborne systems of affected stakeholders in a globally normed manner.[185]

  Yet, voice communication shall still remain a reliable means of communication when it comes to emergencies. Moreover, it will be used as a backup system and for communications with aircraft which are not equipped with the necessary technologies. But as there is no doubt that data communication will replace voice communication as primary means of communication, the term *voice by exception* becomes commonly used.[186]

- **Automatic Dependent Surveillance Broadcast (ADS-B):** As to be able to provide more modern, satellite-based, efficient and safe ATM surveillance capabilities and to replace the reliable, yet increasingly insufficient and obsolete ground-based RADAR technology, SESAR and NextGen strongly rely on the system-wide implementation of

[182] Enea et al. /41/, p. 3

[183] Enea et al. /41/, p. 4

[184] In 2009, EUROCONTROL performed field tests as to measure and optimize FMS accuracy in TBO. Please refer to [Klooster /75/] for further information.

[185] Moreover, the possibility of using the existing ACARS technology for the conduction of TBO has been analyzed by [Klooster /75/].

[186] NCOIC /66/, p. 4

ADS-B when it comes to the tracking of aircraft, both when being airborne and on ground.[187] [188] Moreover, ADS-B will also be used as to track airport ground vehicles; this increases the operational safety, especially when low visibility taxiing has to be performed and/or when airport or airspace traffic density is close to maximum.[189] Thus, according to [EUROCONTROL /77/], ADS-B "relies on aircraft or airport vehicles broadcasting their identity, position and other information derived from on board systems (GNSS etc.). This signal can be captured for surveillance purposes on the ground (ADS-B Out) or on board other aircraft (ADS-B In). The latter will enable […] spacing, separation and self-separation applications".

As ADS-B is essential for the successful implementation of both SESAR and NextGen, all aircraft operated within the European airspace and in excess of 5.7 tons must be equipped with special ADS-B receivers by 2017; in the USA, however, this provision becomes legally binding by the year 2020. Yet, RADAR will remain a back-up system.[190]

- **Decision Support Tools (DST):** As depicted in (Sub-)Chapters 3.4.1 and 4.2, both SESAR and NextGen use the principle of CDM for both long term (strategic) and short term (tactical) planning as well as operational control. Before a decision can be made, all possible solutions to an occurring problem have to be figured out and compared against each other as to be able to choose the one which meets the decision maker's objectives the best. Therefore, Decision Support Tools (DST), capable of performing trajectory predictions whilst accounting for other RBTs from the NOP and other relevant operational information – e.g. weather forecasts, NOTAMs, crew status and TOW – are necessary. Thus, all stakeholders – especially air traffic controllers and cockpit crews, but also other affected stakeholders – will become able to collaboratively conduct 4DT management by sharing and negotiating trajectory data. However, a common, standardized data exchange protocol is needed to ensure system interoperability, for both the SESAR and NextGen initiative. As of today, such a protocol has not been defined yet.[191] [192] This makes further consultation and standardization inevitable.

5.1.4 SUMMARY

Chapter 5 shows how very similar the ConOps of SESAR and NextGen are. They only differ slightly when it comes to methodologies and technology.[193] Moreover, they follow different time horizons, with SESAR being implemented in 2020, five years earlier than NextGen.[194] As of today, total system interoperability between both ATM environments has not been ensured yet, especially when it comes to SWIM, DST and the establishment of a common NOP. This makes further harmonization and standardization, e.g. under the leadership of ICAO, necessary. For the purpose of this thesis – analyzing the impact of SESAR and NextGen on OCCs – it can be summarized that the technological concepts of both ATM initi-

[187] Enea et al. /41/, p. 4f.

[188] The detailed description of how ADS-B works, under which conditions it will be used and how it will be implemented goes far beyond the scope of this thesis. For further information, please refer to specialist literature.

[189] Therefore, ADS-B is essential to the implementation of Advanced Surface Movement Guidance and Control Systems (A-SMGCS). For further information concerning both the concept and implementation of A-SMGCS as well as the role of ADS-B at airport ground operations, please refer to [von Castell /76/].

[190] Enea et al. /41/, p. 4f. and NCOIC /66/, p. 13ff.

[191] Enea et al. /41/, p. 5

[192] For further information, please refer to Klooster et al. /78/ and Vivona et al. /79/

[193] Enea et al. /41/, p. 10

[194] Cp. Chapter 5

atives, in terms of relevant key features and technologies used, are similar to an extent which allows to regard them as being equal. This mainly encompasses their key features SWIM, CDM and 4DT management.

Based on the description of the SESAR initiative (Chapter 3) and the NextGen initiative (Chapter 4), this Chapter 5 served to identify the most important commonalities and differences between SESAR and NextGen as to be able to analyze the outcomes of these ATM initiatives on future Operations Control Centers (OCC) and OCC-cockpit crew workflows in Chapter 7. Before this can be achieved, the general structures as well as processes of an OCC as operated nowadays and recent OCC-cockpit crew workflows will be described in the following Chapter 6.

6 AIRLINE OPERATIONS CONTROL CENTERS TODAY

An Airline Operations Control Center (OCC) is an organizational unit of an airline which is in charge of managing day-to-day operations in order to execute complex flight schedules whilst ensuring both efficient and safe operations. [Bruce /52/, p. 1] regards the OCC as an airline's nerve center which is "responsible for the control of aircraft to ensure economical, operational, and commercial efficiency". All tactical decisions concerning an airline's air traffic operations, e.g. how to address sudden disruptions, are made in the OCC. Therefore, an OCC strongly and continuously influences an airline's economics.[195] [196]

There are internationally binding provisions which – albeit only indirectly – commit airlines to operate OCCs. Hence, ICAO Annex 6, Part 1, 3.1.3 states that "[an aircraft] operator or a designated representative shall have responsibility for operational control".[197] In this context, *operational control* is defined as "the exercise of authority over the initiation, continuation, diversion or termination of a flight in the interest of the safety of the aircraft and the regularity and efficiency of the flight".[198] These provisions – even if they are not very precise and detailed – oblige airlines worldwide to exercise operational control over their flights. As they do not define how operational control has to be ensured, airlines are urged to operate their OCCs according to industry best practices.[199] This mainly encompasses the OCCs structures, processes and workflows. In return, each OCC is operated differently.

In the following, Chapter 6 serves to describe the general purpose, structures and workflows of today's OCCs and, thus, gives an overview of how the current standard setting of an OCC is integrated into the planning process of an airline (Chapters 6.1 to 6.3). As the OCC acts as the airline's operational interface with their cockpit crews, this Chapter also give an insight into how OCC and cockpit crew workflows interact with each other (Chapter 6.4).

6.1 PURPOSE AND INTEGRATION INTO THE AIRLINE PLANNING PROCESS

An OCC represents an airline's organizational unit which is responsible for short term operational planning and the exercise of operational control at the day of operations (DOO). The OCC is an organizational unit which is integrated into short- and long-term airline planning processes. The entire planning process, as depicted in Figure 29 (p. 52), is summarized in the following:

In the long term planning phase, the flight schedules for subsequent flight schedule seasons are developed. This happens at an early stage in the planning process, approximately 12-48 months before a scheduled flight takes place.[200] The development of a flight schedule is based on constant market evaluations as well as estimations and the periodic alteration of demand for air transportation in all markets served. Strategic decisions, such as which city pairs shall be served in which frequencies and at which capacities, shall be made in this phase. Not only the expected market demand, but also factors like aircraft performance and characteristics, manpower, national and international legal aspects and the competitor's approach against the own market activities have to be considered.[201] The highest credo is to

[195] Dellal /47/, p. 1

[196] SESAR JU /43/, p. 122

[197] ICAO /48/, p. 3-1

[198] ICAO /48/, p. 1-8

[199] Dellal /47/, p. 2

[200] This value varies from airline to airline and depends from the airlines' different business models, strategic goals, alliance obligations etc.

[201] Dellal /47/, p. 5

optimize the schedule in a way to maximize the airline's profit and gain market shares, not just seen from the perspective of a single flight, but from the airline's entire transport network.

When a flight schedule – representing a list of all scheduled city pair connections during a certain period of time, usually half a year – has been established, fleet assignment is done in order to assign existing aircraft types to the single connections. Airport adequacy, aircraft availableness, aircraft performance and characteristics play an important role in this phase of planning. E.g., it has to be considered whether the Maximum Take Off Weight (MTOW) and the number of available seats of a certain aircraft type is sufficient to carry the expected amount of passengers over the entire distance. If there are several aircraft types suitable for a city-pair-connection, the one with the lowest Direct Operating Costs (DOC) has to be identified in order to ensure that the airline's profit is optimal.

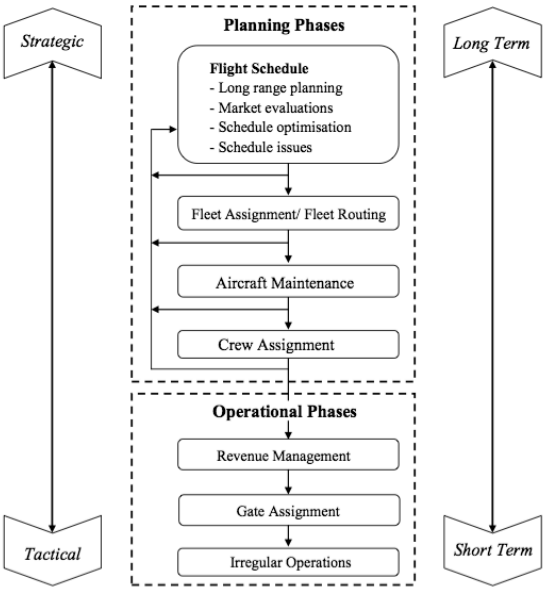


Figure 29: Airline planning and operational phases[202]

After fleet assignment is done, each available aircraft is assigned to a number of routes in a chronological way, following the provisions resulting from both fleet assignment and flight scheduling. This process is also called *tail assignment*.[203] Aircraft Maintenance requirements also have to be considered at this early stage of planning. This results mainly from the fact that not all necessary and legally mandatory maintenance events can be conducted at all served airports for all operated aircraft; it would be too cost-intensive by far to provide all required materials and manpower at every airport, especially when it comes to light (A, B and C checks) and heavy maintenance (IL and D checks) events.[204]

The last step of the strategic planning is the crew assignment, also called *rostering*. During crew assignment, crews have to be assigned to the scheduled flights. Both cockpit and cabin crew members are essential for an airline as they represent indispensable, limited and expensive human resources. Whilst cabin crew members can be assigned "flexibl[y] because they are cross-fleet trained", cockpit crew assignment is more complex as "a pilot can only be assigned to a certain fleet that he or she is qualified to fly".[205] This is why cockpit crew assignment cannot be done before fleet/tail assignment. During the process of rostering, inter-

[202] Bazargan /49/, p. 35

[203] As the unique registration number of an aircraft is printed on its tail, each aircraft can be identified according to it's tail number.

[204] Hüttig /9/

[205] Barnhart et al. /50/, p. 241

nationally binding[206] and airline-intern workload limitations, e.g. resulting from crew union requirements, have to be accounted for. Moreover, flight crew standby, off-time and vacation requests have to be considered. Therefore, most airlines work with bidding and allocation tools based on principles like seniority or first-come-first-served: crew members select their preferred working hours for the following weeks or months and the bidding tool then processes all the input data in a way that the result matches the optimal number of requests and all other boundary conditions, such as legal provisions concerning flight duty times.[207]

After the long term strategic planning phase has been successfully finished, the short term operational planning begins. This is where the OCC takes over responsibility for the control of the airline's operational activities, approximately 72 hours before Estimated Time of Departure (ETD)[208]. During this last pre-flight phase, irregular operations, e.g. disruptions due to severe weather or shortage of suitable and operable aircraft, may force the personnel responsible at the OCC to adjust the pre-planned operations in a way to minimize unforeseen costs, cancellations and delays. In the following, three scenarios shall be given as to illustrate the variety of OCC responsibilities:

- **Scenario 1 (ENG inop)**: Due to a bird strike which occurred during the final approach of the previous flight cycle, the left-outer engine (ENG 1) of a four-engine long-range Airbus A380-800 aircraft is damaged. Before the aircraft may continue its service, accurate maintenance of the damaged engine is inevitable. A detailed analysis of the engine's condition shows that – because of safety reasons – the entire engine has to be substituted before the next flight can take place. But even in the unlikely case that a suitable engine and accordingly trained maintenance personnel is available instantly, the engine replacement itself takes several man-hours. As the whole scheduled aircraft turn-around only takes 90 minutes[209], the aircraft will not be ready for operational usage in time. The OCC is informed by the maintenance department accordingly to search for the most cost- and time-efficient solution to this operational problem. This process of managing operational problems is called *disruption management*. In general, the range of possible solutions encompasses flight cancellation, diversions, tail-reassignment and/or delayed operations.[210]

  In the case given, the OCC decides to change the aircraft, as a cancellation of the flight would be too expensive in terms of passenger accommodation, compensation and rebooking. As there is no other suitable long-range aircraft available on short call, a temporarily unassigned Boeing B747-400 parked at the same airport must be used. But as the cockpit crew assigned initially is not allowed to fly a B747-400 instead of an A380-800, an accordingly-trained standby cockpit crew has to be alerted. As their arrival at the aircraft is delayed due to the short time between notification and scheduled Off Block Time (OBT), the flight will depart with an initial delay of 55 minutes. This means that the OCC has to re-file a slot request for the departure airport. In order to compensate for the initial delay, a so-called *high-speed flight plan* has to be calculated by the OCC. This means that the originally planned optimal cruise speed of Mach 0.85 at FL 350[211] is raised to Mach 0.87 temporarily in order to compensate for the lost time by flying faster. In return, this causes the aircraft to burn more fuel as Mach 0.85 was the optimum cruise speed in terms of balancing fuel and time consumption. Nevertheless, the additional costs for a temporarily higher fuel flow and all

[206] Cp. provisions provided in ICAO Annex 6, Regulation (EC) No. 859/2008 (EU-OPS 1), FAR Part 117 and FAR Part 121.

[207] Dellal /47/, p. 7

[208] Cp. Footnote 200

[209] Airbus Operations /51/, p. 7

[210] Bruce /52/, p. 1

[211] Approximately 35,000 ft above MSL, depending from current mean sea level air pressure (= QNH at MSL)

other costs arising from this solution have been considered as being smaller than the costs resulting from a delayed arrival.

- **Scenario 2 (Medical Emergency)**: Caused by a sudden cardiac infarction of a 55 year old male passenger, 40 minutes after departure from Berlin-Tegel (EDDT) to Bogota (SKBO), a long-range A330-200 aircraft has to perform an emergency landing at London Heathrow Airport (EGLL). 25 minutes after the cockpit crew decided to perform this maneuver and the necessary coordination with ATC has been performed, the aircraft lands safely at EGLL. According to the international provisions defined in [ICAO /69/, p. 3-3], an aircraft in need of an emergency landing shall be given way by all other aircraft in the affected airspace and treated with priority. This, in direct return, affects the local ATM as the other aircraft in this area have to be separated from the incoming emergency flight. Thus, the landing sequence established by the ATC has to be changed in order to ensure that the aircraft with the medical emergency may land as soon as possible. This impact affects other airline OCCs as they need to cope with this situation, especially as they may face disruptions themselves.

  Thus, the fully-loaded aircraft is parked on the apron of an alternate airport. As this is not a situation which may be coped with by the cockpit crew, the airline's OCC has to support the cockpit crew in handling this disruption. After a short phase of decision-making, the OCC advises the cockpit crew that the flight shall be continued after a new flight plan (EGLL-SKBO) has been calculated, the aircraft has been refueled and the crew has been replaced due to international duty time restrictions.[212] This unforeseen turnaround process takes another 120 minutes. During that time, the passengers are requested to leave the aircraft as to ensure both safety, due to refueling the aircraft, and passenger comfort. Once the aircraft has been refueled, a new departure slot has been booked in cooperation with the responsible AFTM entity EUROCONTROL and the new flight plan has been approved by the ATC as well as transmitted to the cockpit crew, the passengers are allowed to board the aircraft again. 165 minutes after the disruption occurred, the aircraft leaves EGLL for SKBO.

- **Scenario 3 (Severe Weather Conditions)**: Due to severe thunderstorm activity combined with strong gusts at Salt Lake City Intl. Airport (KSLC), the runway system of this airport as well as the whole surrounding aerodrome have to be closed by the responsible ATC entity for 60 minutes as the safety of flight operations is no more ensured. This means that all aircraft grounded at KSLC may not depart as scheduled and that some of the incoming aircraft have to initiate diversions as the amount of fuel carried onboard is not sufficient for performing holding patterns that long. Hence, this causes a lot of disruptions throughout the entire region and negatively influences all affected ATM stakeholders – especially airspace users, but also airports, the ATC and ground handling agents – as surrounding airports with limited airspace and airport capacity have to compensate the sudden breakdown of KSLC airport on short notice. Thus, the whole regional ATM environment is affected.

  As seen from the individual airline's point of view, such a situation is extremely difficult to handle as it has to ensure that an individual solution is found for every single of their aircraft operating in this region; the highest principle is ensuring safety, followed by minimizing the negative financial outcomes of such a situation of force majeure. In the beginning, the OCC has no other chance than supporting the individual cockpit crews in re-filing their ATC clearances and in re-booking AFTM slots as to get permission to initiate an alternate landing. Once landed at the alternate airport, the OCC has to handle the passengers as they did not reach their intended destination. This means that a suitable, economically justifiable solution has to be found, e.g. by realiz-

[212] Cp. provisions provided in ICAO Annex 6, Regulation (EC) No. 859/2008 (EU-OPS 1), FAR Part 117 and FAR Part 121

ing delayed onward flights. This, in direct return, means that both aircraft and flight crew re-allocation have to be performed. Moreover, new ATFM slots have to be requested and new flight plans have to be filed. During this time of decision making and realization, passenger compensation regulations are not applicable as the upcoming of a thunderstorm is considered as force majeure. Passengers have to be accommodated during the time, they have to wait for a connecting flight as the entire rescheduling of flights is a very complex, time-consuming process. Therefore, this entire situation imposes huge costs on the affected airlines.

As these three scenarios given above show, not only irregularities have to be handled by the OCC during short term operational planning, but also revenue management, gate as well as fleet and crew assignment have to be considered. As the decisions being made in an OCC are almost ever significant ones, only one inaccurate decision can make the difference between an airline's survival and its bankruptcy, according to [Bruce /52/, p. 1]. This also – but not exclusively – includes situations which could not be foreseen and/or proactively responded to.[213] However, the both the avoidance of and recovery from complex and/or unforeseen disruptions requires expeditious and accurate decision making by the OCC personnel. Therefore, reliable and up-to-date information on the current situation is need in order to make appropriate decisions.[214] The standardization of operational tasks and the centralization of decision making helps to achieve operational proficiency and enhances the overall

- safety,
- dependability,
- efficiency,
- cost effectiveness, and
- growth potential

of an airline's operation.[215] Thus, the OCC is essential to the success of an airline, both seen from the operational (short term) and strategic (long term) point of view.

The following Chapter 6.2 shall give an overview of the standard setting of an OCC and the functional groups represented within.

6.2 STRUCTURE OF A TYPICAL OCC

Regarding the structure of a typical OCC, [Bruce /52/, p. 1] states the following:

> "An OCC may vary in terms of location, physical structure, and composition. It may consist solely of a group of decision-makers with responsibility for coordinating and controlling aircraft movements, or more typically, may include representatives from pilot and cabin attendant crewing, engineering, flight dispatch, various airline commercial and customer service functions, air traffic control liaison, airport liaison, and meteorology".

In the following, an outline of the typical setting of an OCC is described. As there are no binding legal provisions on how an OCC has to be organized and operated[216], the information given by [Dellal /47/] and [Jeppesen /53/] – combined with interviews conducted with Mr Ib-

[213] The eruption of the Icelandic volcano Eyjafjallajökull in 2010 serves as a good example: volcanic ash clouds are highly hazardous to airborne aircraft as the ash contained in the clouds can damage running engines as the ash melts once sucked into the hot engine. This bares the risk of a situation where all engines become inoperable at once (AEI). Moreover, cockpit windshields may blur due to the sandblasting effect which occurs at cruise speed of approximately 900 km/h.[213] Thus, back then in 2010, large parts of the European airspace were affected by airspace constraints; the OCCs had to handle this very complex situation and, in most cases, could only try to cut the losses.

[214] Bruce /52/, p. 1

[215] Jeppesen /53/, p. 6

[216] Cp. Chapter 6

rahim Gülcan (Air Berlin, Manager OCC)[217] and Mr Hermann Lindner (Air Berlin, Political Affairs)[218], serve as references on how the standard setting of an OCC looks like nowadays.

As to be able to achieve the highest level of operational efficiency and responsibility, the standard OCC represents a centralized organization which is organized in both *Core* and *Represented Functional Groups*, as shown in Figure 30.

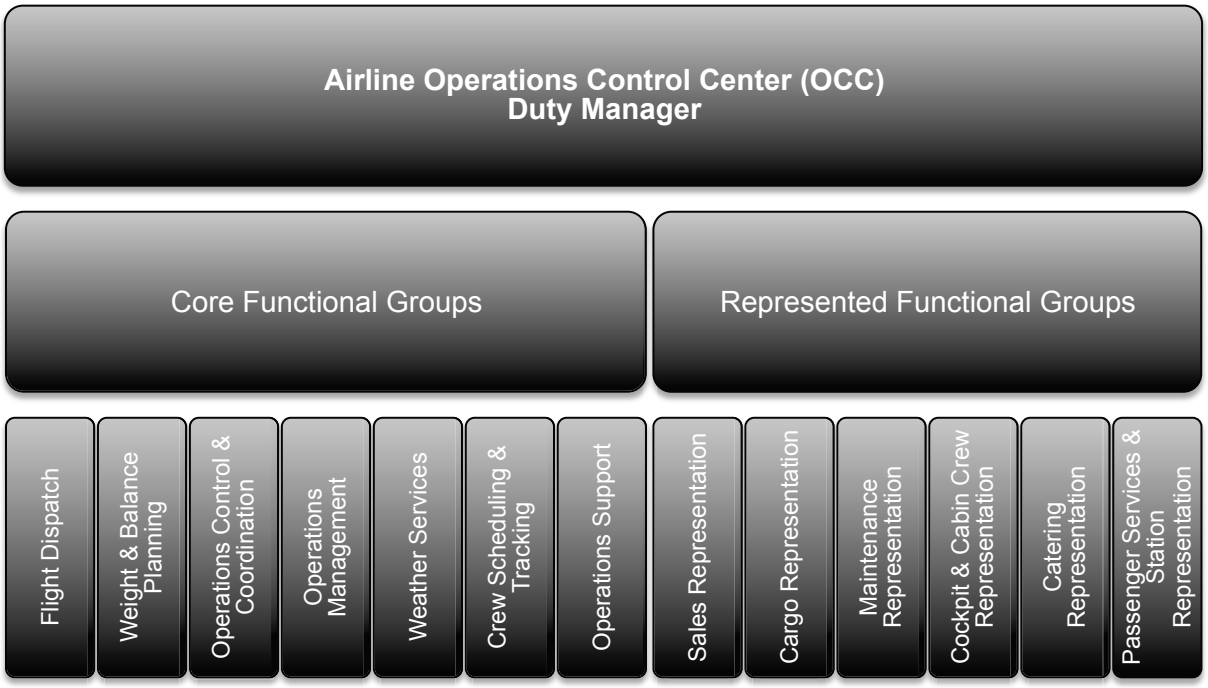


Figure 30: Structure of a typical OCC[219]

The terms *core functional groups* and *represented functional groups* differ as follows:

- **Core functional groups**: This includes the functional groups which are of essential importance for the efficient, economically-viable and safe conduct of airline operations at the DOO, e.g. Operations Control and Coordination, Crew Scheduling and Tracking, and Flight Dispatch.
- **Represented functional groups**: This includes the remaining functional groups which have, in general, a minor influence on current airline operations as they usually do not endanger the conduction of scheduled flights, even if irregularities occur. In fact, they help to improve an airline's operations, e.g. in terms of efficiency and passenger comfort, and represent interfaces to other OCC-relevant departments within the airline, e.g. the maintenance department.

Depending on the size of the airline and the complexity of the operated network, the size of an OCC, being led by an OCC manager who reports directly to the airline's flight operations manager, may vary significantly. The amount of staff working simultaneously can range from only 15-20 employees (e.g. low cost carriers which only operate a moderate amount of short range flights using point-to-point connections) to hundreds of employees (e.g. network carriers which operate a huge amount of short and long range flights using hub-and-spoke connections).[220]

---

[217] Gülcan /54/

[218] Lindner /55/

[219] Author's own illustration

[220] Dellal /47/, p. 10

The following two Subchapters 6.2.1 and 6.2.2 serve to highlight the individual Functional Groups depicted in Figure 30.

6.2.1 CORE FUNCTIONAL GROUPS

In the following, the different core functional groups being integrated in an OCC are described:

- **Operations Management**: The *Operations Management* represents the airline's corporate management in the OCC and is, from the operational point of view, ultimately responsible for all operations of the airline. Their main tasks encompass issuing operational bulletins and procedures concerning OCC-internal workflows as well as reporting steadily the current status of operations to the upper management. The *Operations Management*, moreover, has to take care that the conduction of daily operations is compliant with the airline's internal procedures, legal provisions, trainings and corporate culture. This is why *Operations Management* defines the daily operational plan as to ensure that the airline's strategic goals and objectives are linked to their tactical goals and objectives. This task follows the airline-intern process from strategic to tactical planning which has been depicted in Figure 29.[221] Thus, this core functional group represents the airline's interface which connects long and short term planning and manages the OCC. *Operations Management* is led by the OCC Duty Manager. He or she is ultimately responsible for centralized final decision making, both for ordinary operational issues and when it comes to emergency or exceptional conditions, e.g. hijacking or accidents.

- **Flight Dispatch**: *Flight Dispatch* covers all aspects of flight planning, flight following and ATFM slot coordination and acts as the flight crews' ears and eyes on the ground as this functional group aims at ensuring the safety, legality and efficiency of flight operations whilst taking care of passenger comfort. The main tasks of the *Flight Dispatch* are to both control and monitor all flight operations from origin to destination and to generate Operational Flight Plans (OFP) as well as ATC flight plans. In order to be able to do so, flight dispatchers have to be trained in terms of interpreting NOTAMs, TAFs, METARs and weather charts and need to be aware of aircraft performance, weight and balance, airport suitability, air navigation, fuel calculation and both legal as well as internal provisions. Moreover, the *Flight Dispatch* serves as the airline's interface with the ATM as the dispatchers are responsible for filing ATC flight plans and requesting ATFM slots. When monitoring flights, dispatchers provide airborne flight crews with current en-route and destination weather reports and forecasts by using ACARS. All other information which is important to the safe and efficient conduction of the flight followed are also transmitted steadily, e.g. information on runway closure and restricted airspace.

- **Weight and Balance Planning**: The main task of this functional group is to develop loading plans for flights based on information on how many passengers will board the aircraft, how many bags they will carry and how much freight and/or mail will be carried in the cargo compartment of the aircraft. The *Weight and Balance Planning* results in a load & trim sheet which states, amongst other items, the Zero Fuel Weight (ZFW) of the aircraft, the mandatory fuel components required for the intended operation and the Center of Gravity (CG), which has huge influence on fuel-consumption and the trim of the aircraft. As it often happens that passengers buy a ticket, but do not attend their flights (so-called *no-shows*), *Weight and Balance Planning* has to be reviewed and updated several times before the flight takes place. Once generated, the resulting load & trim sheet has to be provided to the flight crews, as it is an essential part of the crew briefing package. Thus, the *Weight and Balance Planning* has to

[221] Cp. p. 52

coordinate with *Flight Dispatch* handing over relevant information to the cockpit crew. Moreover, a loading plan has to be submitted to the departure airport. This is then used as reference for the loading and fueling of the aircraft by the responsible ramp agent.

- **Operations Control and Coordination (Flight Following)**: The main task of this functional group is to resolve schedule disruptions and/or minimize their outcomes on behalf of *Operations Management*, which is led by the OCC Duty Manager. Therefore, the current overall status of the flight operations has to be monitored, analyzed and evaluated. This function is also called *Flight Following* and is performed in close cooperation with the *Flight Dispatch*. If irregularities are detected, corrective actions have to be planned, initiated and directed. Moreover, *Maintenance Representation*[222] has to be informed and consulted accordingly if aircraft routings have to be changed. This is due to the fact that maintenance events have to be considered when it comes to scheduling of aircraft as not all maintenance events can be performed at all stations.[223] Disruption can be caused by many reasons, amongst others severe meteorological conditions, airport and/or airspace closure or congestion, crew member shortage, inoperable aircraft, missing spare parts or medical emergencies necessitating a precautionary or emergency landing. There are many possibilities on how to react to disruptions, be it delayed operations, flight cancellations, en-route diversions, aircraft tail number or aircraft type changes, or the conduction of ferry flights[224] as well as additional and charter flights. When it comes to the decision making which of these possibilities should be chosen in order to restore the flight schedule as best as possible, both passenger convenience and additional costs have to be considered. Whilst low cost carriers prefer minimizing their costs with only little regard for their passengers' convenience, network carriers also have to take into consideration that their passengers are willing to pay higher ticket prices as they have higher expectations regarding comfort, service, reliability and punctuality.

- **Weather Services**: This functional group is responsible for providing current weather information and forecasts. Weather conditions for the airline's entire route system have to be monitored and analyzed by means of modern technology, e.g. satellite pictures and atmospheric measurements. This allows for precise forecasting of local, regional and global weather events and provides information on how long they will last and where they will be located. As flight operations are heavily influenced by weather events in general, all relevant information is provided to *Flight Dispatch*, flight crews and *Operations Control and Coordination*. This is important as not only the safe, but also the efficient conduction of flights depends on weather events. E.g., it might be efficient to take a flight route which is longer but less affected by strong head winds. If necessary, *Weather Services* also gives advice on how to react on severe weather conditions, e.g. by suggesting diversions in order to avoid thunderstorm or hurricane activity.

- **Crew Scheduling and Tracking**: This functional group coordinates the crew scheduling and interacts with the crew rostering department in order to ensure that a qualified cockpit and cabin crew are assigned to each flight. Moreover, *Crew Scheduling and Tracking* has to monitor crew sign-ins as well as whether all legal provisions regarding duty times and flight hours are obeyed accordingly.[225] In case of crew mem-

[222] Cp. (following) Subchapter 6.2.2

[223] Cp. *Scenario 1 (ENG inop)* given in Chapter 6.1

[224] A ferry flight is a non-commercial flight which is conducted for the purpose of moving an aircraft from place A to B, e.g. in order to repair or overhaul the aircraft or to be able to offer a commercial flight which departs at B.

[225] Cp. provisions provided in ICAO Annex 6, Regulation (EC) No. 859/2008 (EU-OPS 1), FAR Part 117 and FAR Part 121

ber shortage, e.g. because of crew member sickness or an aircraft change, cockpit and/or cabin crew members have to be re-allocated or additional standby crews have to be informed that they have to take over duty on short notice. In order to fulfill their tasks, *Crew Scheduling and Tracking* coordinates with *Flight Dispatch* and *Operations Control and Coordination*. E.g., as it is an industry's best practice that flight crews use their own airline's flights to get to the airports where their next flight departs from, it may happen that a flight crew arrives delayed as their connecting flight is delayed. In such cases, *Crew Scheduling and Tracking* has to advise *Operations Control and Coordination* accordingly and is responsible for making any arrangements necessary that this incident has as little influence on all of the airline's scheduled flights as possible.

- **Operations Support**: *Operations Support* includes a lot of specialists who provide support in various operational areas, amongst others:
  - NOTAM analysis,
  - operations performance engineering (e.g. development, implementation and evaluation of new OCC procedures aiming at lowering operational costs or improving disruption management),
  - operations analysis (e.g. generation of delay statistics),
  - ATC coordination (e.g. temporary, ample airspace closures), and
  - systems and database administration.

6.2.2 REPRESENTED FUNCTIONAL GROUPS

In the following, the diverse functional groups being represented in an OCC are described:

- **Sales Representation**: This functional group is responsible for passenger reservations and revenue management information. Moreover, when it comes to disruptions, *Sales Representation* provides *Operations Management* as well as *Operations Control and Coordination* with real time sales figures so that the economical outcome of various possible solutions to an operational problem can be compared objectively.
- **Cargo Representation**: This functional group represents the cargo department within the OCC. Cargo is often transported in the cargo compartments of aircraft which are primarily used for passenger transportation, as this helps to increase operational revenues. Thus, airlines try to transport cargo whenever possible. The overall mass of cargo which can be transported aboard mainly depends from the Maximum Take Off Weight (MTOW) which must not be exceeded when the initiates take off at the Brake Release Point (BRP).[226] As airlines have contracts with freight forwarders, the cargo representatives have to ensure that scheduled cargo is transported in time and as agreed upon. Thus, the cargo schedule has to be adapted to operational and technical constraints, e.g. if disruptions occur or the MTOW of an aircraft is exceeded because of cargo issues.
- **Maintenance Representation**: As the strategic and tactical planning of maintenance events is a complex task itself, airlines establish so-called *Maintenance Control Centers* (MCC). Such a MCC is usually not part of the airline's OCC, but as it has been described in Chapter 6.1, maintenance planning is an important aspect the whole operational planning process of an airline, both from the strategic and tactical point of view. Therefore, the MCC is represented in the OCC. Whilst the maintenance representatives hand on real time information on fleet serviceability to *Operations Man-*

[226] Cp. Figure 23 (p. 26)

agement as well as *Operations Control and Coordination*, the OCC – in return – provides the MCC with all information relevant for maintenance planning. Moreover, *Maintenance Representation* supports the OCC's work by sharing maintenance-related knowledge and experience, by ordering aircraft spare parts urgently needed on short notice or by considering the legal aspects of aircraft serviceability. E.g., *Maintenance Representation* gives advice on whether aircraft serviceability is still provided according to the Minimum Equipment List (MEL) and Configuration Deviation List (CDL) when certain components or systems of an aircraft are temporarily unserviceable or only serviceable to some extent.

- **Cockpit and Cabin Crew Representation**: This functional group shall mainly ensure operational continuity throughout an airline's entire operational network and serve passenger convenience while adhering to the airline's corporate culture and defined workflows. Moreover, it shall address safety-relevant aspects of operations which can be influenced by crew members or which crew members as well as passengers might be affected from. This encompasses, e.g., advising the *Operations Management* on how to handle flights which are affected by severe weather conditions.
- **Catering Representation**: In order to ensure passenger convenience even if disruptions occur, the airline's catering department is represented in the OCC.[227] Thus, in case of operational irregularities, the *Catering Representation* tries to find solutions as to be able to offer onboard services even if operational changes, e.g. gate or aircraft changes, come to pass.
- **Passenger Services and Station Representation**: This functional group acts as liaison between airport passenger services and the OCC. Their main task is to coordinate passenger re-accommodation when severe schedule disruptions or passenger over-sales occur. Moreover, this functional group is responsible for passing on all relevant information to the airline's stationed ground personnel, e.g. disruption recovery plans.

As the structure of a typical OCC as well as single functional groups integrated into it have been discussed in this Chapter, the following Chapter 6.3 serves to depict the overall OCC workflow.

6.3 CONVENTIONAL OCC WORKFLOWS

If one combines all of the functional groups' various tasks as described in the Subchapters 6.2.1 and 6.2.2, an overall OCC workflow can be derived. This workflow, being illustrated subsequently in Figure 31 (p. 61), represents the tactical phase of operational planning and, thus, covers the last 72 hours before the Estimated Time of Departure (ETD) of a scheduled flight.[228]

[227] Even if catering varies from airline to airline and may be outsourced, all commercial airlines are dependent from offering catering and/or onboard retail services as to increase passenger convenience and/or onboard revenues.

[228] Cp. Chapter 6.1

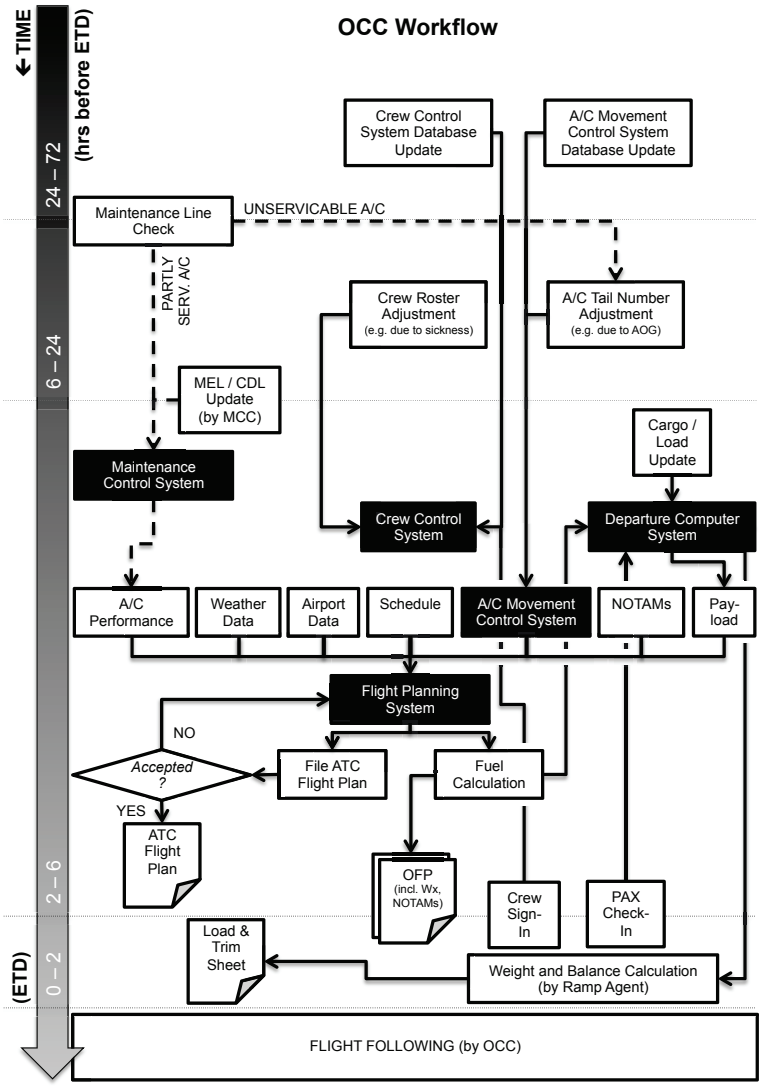


Figure 31: OCC workflow (last 72 hours before ETD)[229][230]

This workflow and its four different phases are described in the following.[231]

- **Phase 1: 72 to 24 hours before ETD**: In this phase, database updates for both the *Crew Control System* and the *Aircraft Movement Control System* are performed. Whilst the first system allows for the control of all the airline's crew members' duty rosters, the second system is used to control and monitor all aircraft of an airline's fleet, as to be aware of when and how long which aircraft will be at which airport. Furthermore, scheduled maintenance events and additional information like, e.g., the aircraft's status can be monitored by means of this system. As there is a seamless transition between the strategic and tactical planning phases[232], the information resulting

[229] Author's own illustration; based on [Dellal /47/, p. 9 and 18]

[230] All black-colored rectangle items represent IT systems. All white-colored rectangle items represent OCC processes, OOC-relevant events or input data. Documentation material (such as OFP) is illustrated as white paper sheet. The size of the items does not correspond to the complexity and/or endurance of the related processes. Moreover, the vertical positioning of the items assigned to one phase does not correspond to their timely beginning. This means, e.g., that the process 'PAX Check-In' does not necessarily start simultaneous to the process 'Cargo / Load'; however, both begin during the last six to two hours before ETD.

[231] All terms written *in italics* represent systems, functions or processes depicted in Figure 31.

[232] Cp. Chapter 6.1

from the crew assignment process – which has been performed during the phase of strategic planning – have to be transmitted to the *Crew Control System*; the information concerning aircraft movement control is derived from the tail assignment process which also initially considers regular aircraft maintenance requirements.[233]

If an aircraft becomes unserviceable during the last 72 hours before ETD, this is usually detected during regular line maintenance events or due to crew reports stating that malfunctions have been observed during operations. In both cases, the maintenance department is notified and will trigger an *Aircraft Tail Number Adjustment* when it is conceivable that the aircraft will not be serviceable in time for the scheduled operation.[234] The tail number re-assignment itself will be done by the Flight Dispatch, once notified accordingly. Of course, there are other events which may trigger an *Aircraft Tail Number Adjustment*, e.g. the delayed arrival of an aircraft. This is due to the fact that a delay influences the succeeding scheduled operation with this aircraft, since the turn-around process has to be postponed due to the late arrival. In such cases, *Aircraft Tail Number Adjustment* – if applicable – may be an adequate solution in order to minimize or even avoid following delays.

However, if the aircraft is not fully serviceable but still ready for operational usage[235], both the *Minimum Equipment List* (MEL) and the *Configuration Deviation List* (CDL) have to be updated in the *Maintenance Control System* which is a system used for the operational planning, control and monitoring of all relevant maintenance events and processes. This is done by the *Maintenance Control Center* (MCC) which is – as a counterpart to the OCC – responsible for operational maintenance planning and monitoring. Once updated to the *Maintenance Control System*, the information about the malfunctions is processed in a way to analyze the outcomes on *Aircraft Performance*. If the aircraft is fully serviceable, no further actions have to be taken by the MCC.

- **Phase 2: 24 to six hours before ETD**: During this phase, *Crew Roster Adjustment* has to be performed, e.g. if a crew member becomes sick or is prevented for any other reason and may not attend his/her shift on short notice. The outcomes of adjusting the crew roster have to be updated to the *Crew Control System*. *MEL/CDL Updates* and *Aircraft Tail Number Adjustments* are also usually performed during this phase if problems occur, but may also have been performed in advance, according to the particular situation.

- **Phase 3: Six to two hours before ETD**: This phase is the most significant phase in terms of OCC workflows as it covers several critical processes which may significantly influence the timely departure of a scheduled flight.

  The main element of this phase is the *Flight Planning System* which is a system being used by the Flight Dispatch in order to create both the *ATC Flight Plan* and the *Operation Flight Plan* (OFP)[236] and to perform the *Fuel Calculation*. Therefore, several input data and information is needed, especially concerning *Aircraft Performance*, current Weather reports and forecasts (*Weather Data*), *Airport Data*, *Schedule*, *Aircraft Movement Control*, *NOTAMs* and planned *Payload*. Once inserted in the *Flight Planning System*, all these data is processed and both the *ATC Flight Plan* and the *OFP* are generated automatically; if necessary, the Flight Dispatcher may change and adapt the generated documents in a way to optimize operational efficiency or

[233] Cp. Chapter 6.1

[234] This case, meaning that an aircraft is unserviceable due to unsolved technical problems, is referred to as *AOG* (Aircraft On Ground).

[235] E.g. because of a malfunctioning APU

[236] Cp. Definitions for additional information.

meet other objectives, e.g. by increasing the given cruise speed as to make up for delays.[237] According to ICAO SARPs, the final *ATC Flight Plan* has to be filed to ATC at least one hour before ETD if IFR operations are intended.[238] This usually happens via a broadband data link between OCC and ATC. As it may happen that the ATC does not accept the *ATC Flight Plan*, e.g. due to missing specifications or airspace constraints, both the *ATC Flight Plan* and the *OFP* have to be re-calculated according to the ATC provisions and sent to the ATC again. Once the *ATC Flight Plan* has been accepted by the ATC, the OFP is provided to the cockpit crew. This must not necessarily happen more than two hours before ETD as the cockpit crew will – in most cases – not be present yet.

Meanwhile, the *Passenger Check-in* begins. This process lasts approximately until one hour before ETD, but this may depend on many factors, such as airport layout and terminal complexity, intended operations (short or long range), prescribed security screening procedures etc. Once all passengers have checked in, this information is provided to the *Departure Control System* (DCS) which is a system used for the operational management and control of an airline's *Passenger Check-in* and *Cargo Load* processes. Once the number of checked-in passengers and the mass and dimensions of additional *Cargo Load* which is transported aboard a passenger aircraft is known and inserted in the *DCS*, the calculation of the *Payload* mass can be done. This mass is needed, amongst others, in order to both calculate the *Aircraft Performance* for all phases of flight and to perform the *Fuel Calculation* correctly. Moreover, the airline has to be aware of which passengers have checked-in their baggage as the baggage of passengers who have checked-in but did not board the plane has to be unloaded for security reasons before the flight takes place.[239]

- **Phase 4: Less than two hours before ETD**: This phase is the last before the departure and covers several OCC-related processes synchronously.

  The *Passenger Check-in* process, ending approximately one hour before ETD, is still in progress, as described above. Meanwhile, the *crew signs in* at the airport approximately two hours before ETD[240] as they need some time to prepare themselves before the flight takes place, e.g. as they have to get their *OFP*[241] and have to discuss the assigned operation. Once signed-in, this information is updated to the *Crew Control System*. If there is any problem, e.g. if a crew member arrives late at the airport due to a traffic jam, the OCC contacts the crew to decide how to handle this situation in order to avoid a negative outcome to the airline's operations.

  Furthermore, *Weight & Balance* has to be accounted for by the *Ramp Agent* who is an airline employee responsible for controlling the aircraft turn-around and loading processes. The Ramp Agent serves as the OCC's interface with the cockpit crew during this phase and acts as an apron manager who supports, controls and monitors all stakeholders of the turn-around process, as they are, e.g., crew members, cargo

[237] Cp. *Scenario 1 (ENG inop)* given in Chapter 6.1

[238] Depending on the country where the flight begins, this value may vary; cp. provisions provided in ICAO Annex 2, 3.3.1.4: "Unless otherwise prescribed by the appropriate ATS authority, a flight plan for a flight to be provided with air traffic control service or air traffic advisory service shall be submitted at least sixty minutes before departure […]". For Germany, cp. AIP Germany, ENR 1.10, 2.1: "Flight plans shall be filed 120 hours, or five days, at the earliest but no later than 60 minutes prior to the estimated off-block time (EOBT)". For the USA, cp. AIP United States of America, ENR 1.10, 5.1.1: "Pilots should file IFR flight plans at least 30 minutes prior to estimated time of departure to preclude possible delay in receiving a departure clearance from ATC".

[239] Cp. provisions provided in ICAO Annex 17, 4.5.3

[240] This value may vary depending on whether a short or long range flight has to be conducted.

[241] There are several ways for the cockpit crew to get the OFP; the most common is that the airline provides some terminal PCs where the cockpit crews can access the OFP by loading it onto their Electronic Flight Bag (EFB) or by printing it.

loaders, catering as well as cleaning personnel and fueling agents. Another responsibility of the *Ramp Agent* is to ensure that the maximal loads and Center of Gravity (CG) limitations of the aircraft are not exceeded.[242] The aircraft's pre-flight CG is determined by the Ramp Agent. Moreover, the *Ramp Agent* issues the *Load & Trim Sheet* to the cockpit crew by signing it. This sheet contains, amongst others, information on the initial CG, the Zero Fuel Weight (ZFW), the Take Off Weight (TOW), the Landing Weight (LW), the Fuel On Board (FOB), the pitch trim setting for take-off, the (final) number and overall mass of passengers aboard as well as the amount and characteristics of the cargo loaded.

As the final Taxi Weight (TW) of the aircraft may change during the turn-around process, e.g. due to passenger no-shows or short term changes in the *Cargo Load* process, the *Load & Trim Sheet* is usually submitted to the cockpit crew only some minutes before the aircraft leaves its parking position. This is because the whole process of *Fuel Calculation* is an iterative one: on the one hand, the overall mass of the aircraft influences the fuel needed in order to conduct a flight; on the other hand, if more fuel is filled into the tanks of the aircraft, this increases the overall mass. The mass, however, influences the aircraft's CG, which, in return, influences the pitch trim necessary for take-off. As this is a complex process and it would be time-consuming to generate the *Load & Trim Sheet* several times, *Ramp Agents* usually issue it only shortly before ETD.

Whereas this Chapter described the conventional OCC workflows, the following Chapter 6.4 serves to highlight the interactions between OCC and cockpit crews during all phases of operational planning and control.

6.4 INTERACTION OF OCC AND COCKPIT CREW WORKFLOWS

Based on information derived from both [Barraci et al. /57/] and [Hankers /59/], this Chapter shall depict the interactions of cockpit crews' normal-operations workflows with those of OCCs', as described in Chapter 6.3. In this context, the term *cockpit crew*[243] refers to a group of at least two commercial pilots jointly operating a multi-pilot aircraft according to the *Multi Crew Cooperation* concept (MCC)[244] in order to fulfill a common mission successfully.

A pilot's work does not only encompass the flight itself but also phases for preparation and follow-up care; these phases have to be considered when the conventional workflow of cockpit crews shall be analyzed. Figure 32 (p. 65) illustrates – derived from the definitions of flight phases as used by both [ICAO /58/, p. 1ff.] and [FAA /63/, p. 28] – a sequence of cockpit crew workflow phases which have been identified as being important for the successful conduction of flight operations in general and of an individual flight in particular. This also

[242] As the aircraft burns fuel during flight, it losses weight constantly. This, in return, makes the aircraft alter its CG. The Ramp Agent has to ensure that the CG never exceeds the allowed limits during all phases of flight.

[243] The main objective of a cockpit crew is to interact in a way that a given flight can be conducted in a safe as well as cost- and time-efficient way respecting passenger comfort and complying with the international and national legal framework and provisions. As the principle of safety comes always first in aviation, the most essential part of a pilot's work is to fly and navigate the aircraft in a way that damage to or loss of both persons and property can be avoided. But, as pilots have to meet several other objectives simultaneously, they also have to manage many other processes which requires them to "interact with and monitor a substantial amount of variables to ensure [both] safety and efficiency […]", as stated by [Barraci et al. /57/, p. 1].

[244] Cp. Acceptable Means of Compliance and Guidance Material to Commission Regulation (EU) No 1178/2011 of 3 November 2011 laying down technical requirements and administrative procedures related to civil aviation aircrew pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council.

includes pre- and post-flight phases which take place both outside of the aircraft (indication: *GND*) and at the flight deck (indication: *FLTD*).[245]

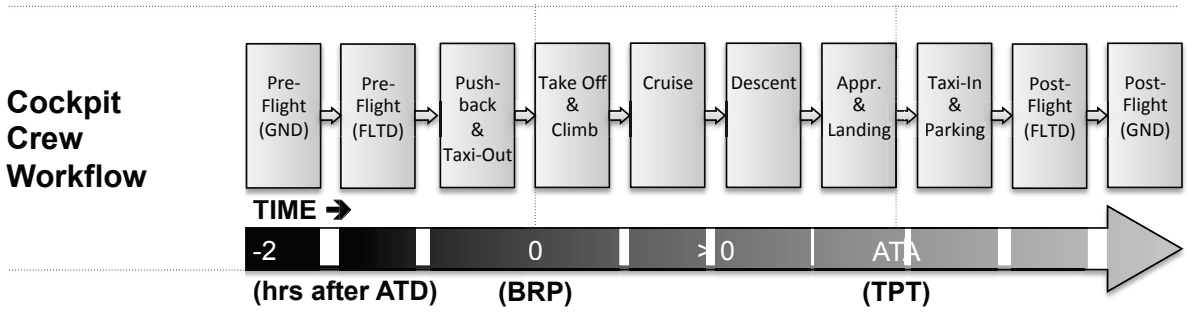


Figure 32: Cockpit crew workflow phases[246]

In the following, the individual phases of a cockpit crew's workflow – being applicable for all domains of operation, as they are short, medium and long range flights as well as passenger and cargo flights – shall be summarized in a way to identify OCC / cockpit crew interactions:

- **Pre-Flight (GND)**: This phase covers all activities of the cockpit crew members which are performed on ground at the airline's OCC or briefing room at the departure airport before they board the aircraft. This mainly encompasses receiving and studying the OFP, NOTAMs, weather reports and any other information relevant for the upcoming flight (such as MEL/CDL) as provided by the OCC, e.g. at a crew member login station. Moreover, a pre-flight briefing with the other cockpit and cabin crew members is performed during this phase in order to prepare for the common flight. Furthermore, the fuel-filling strategy has to be discussed as the commanding cockpit crew member may, depending on his/her operational philosophy, order extra fuel on top of the amount of fuel proposed within the OFP. If necessary, the cockpit crew members also use this phase to contact the OCC's Flight Dispatch in order to discuss or order flight plan changes which become operationally necessary due to bad weather forecasts, disruptions or airspace congestions. The duration of this phase essentially depends on the distance of the flight which shall be conducted. This is due to fact that more operationally relevant information, e.g. derived from NOTAMs and weather reports/charts, have to be studied and discussed.

- **Pre-Flight (FLTD)**: Once finished the Pre-Flight (GND) phase, the cockpit crew enters the aircraft's Flight Deck (FLTD) and prepares the aircraft for take off by performing safety and visual checks (walk-around), powering up the aircraft, setting up aircraft systems (such as air condition and navigation computers) and inserting all relevant data[247] into the Flight Management System (FMS). An ATC en-route clearance has to be obtained in order to open the ATC flight plan which has been filed by the OCC in advance[248]. In addition, aircraft take off performance has to be calculated "based on scheduled mass and balance without having received final loads yet […]. Once the actual values are received by means of the loadsheet, the activity is revisited and checked or adapted if required".[249] [250] If necessary, changes to the OFP, e.g.

[245] As it is not the aim of this thesis to analyze every single process and task a cockpit crew has to fulfill but to compare how SESAR and NextGen may possibly influence the interaction between an OCC and a cockpit crew, some phases – e.g. Pushback & Taxi-Out – have been concentrated.

[246] Author's own illustration

[247] These data, mainly concerning the routing, fuel, aircraft performance and weather data, are derived from the Operational Flight Plan (OFP) and the Automatic Terminal Information Service (ATIS).

[248] Cp. Chapter 6.3

[249] Barraci et al. /57/, p. 5

[250] Cp. Chapter 6.3

affecting the routing, cruise flight level and/or speed of the flight, can still be discussed and realized between OCC and cockpit crew during this phase.

- **Pushback & Taxi-Out**: During this phase, the cockpit crew begins to move the aircraft on the aerodrome surface as both the pushback is conducted and the aircraft is taxied to the assigned runway. During this phase, there is usually no contact to the OCC as the cockpit crew must not be distracted while performing taxiing and preparing the aircraft for take off synchronously.

- **Take Off & Climb**: Once lined up at the assigned runway and cleared for take off, the cockpit crew initiates take off by releasing breaks and applying take off thrust at the Break Release Point (BRP). This point in time is called Actual Time of Departure (ATD). During this phase, there is usually no contact to the OCC as this phase of flight is, along with the Approach & Landing phase, one of the most demanding in terms of pilot workload and concentration. As the main objective during this phase of flight is to get airborne safely, US American Regulations demand that unnecessary distractions have to be minimized when performing flight operations below 10,000 ft. European Regulations are, with regard to content, similar to this.[251]

  Thus, operational changes not relevant to safety must be discussed with the OCC when the aircraft has passed FL 100. However, when a unforeseen landing becomes necessary immediately, the cockpit crew has to inform the OCC that an alternate airport has to be approached. As one OCC core activity is Flight Following, this new situation must then be managed by the OCC as the responsible flight dispatcher has to assist the cockpit crew in searching a suitable alternate airport.[252] Moreover, the OCC's Operations Control and Coordination group has to manage the operational outcomes of this situation as the airline's schedule will by severely disarranged.

- **Cruise**: The Cruise phase begins when the initial Top of Climb (T/C) is reached. During this phase, the cockpit crew's workload is reduced. Their main tasks encompass monitoring the aircraft as well as airspace status (e.g. remaining fuel, engine parameters as well as weather and traffic along the route) steadily as to remain fully aware of the entire situation and obeying ATC instructions; usually, the cockpit crew does not fly the aircraft manually in this phase of flight but uses the autopilot function. All major changes in routing, cruise flight level or cruise speed, for whatever reason, are conjointly discussed by the cockpit crew and the OCC's Flight Following department during this phase of flight. After having found a solution, Flight Following calculates a new OFP which is then transmitted to the aircraft by means of communication technologies such as ACARS, CPDLC or SATCOM.

  The Cruise phase is finished once the Top of Descent (T/D) is overflown. This is the point where, depending on aircraft performance, the descent has to be initiated in order to burn as less fuel as necessary for the remaining distance.

- **Descent**: During this phase of flight, starting at the T/D, the descent is performed. As the cockpit crew is not yet approaching an airport but is gradually beginning to reduce altitude constantly, flight plan changes may be still made in cooperation with the OCC's Flight Following. Yet, following the EU-OPS 1 and FAR Part 121 provisions stated above, unnecessary distractions, amongst others due to communicating with the OCC, have to be ceased as soon as the aircraft is at or below FL 100. The Descent phase is finished when the aircraft reaches the Initial Approach Fix (IAF).

- **Approach & Landing**: Once having overflown the IAF, the Approach & Landing phase begins. This phase is the most challenging, as the crew workload is high and

[251] Cp. EU-OPS 1, 1.085 and FAR Part 121.542

[252] Cp. Subchapter 6.2.1 and Chapter 6.3

the aircraft flies at ground level, which means that aircraft and airspace status have to be checked steadily as to ensure situation awareness and safety at all times; Moreover, the ATC radiotelephone traffic usually increases as the aircraft approaches the Terminal Manoeuvring Area (TMA) of the arrival airport. Therefore, the cockpit crew's interaction with the OCC is ceased during this phase of flight as long as no alternate landing becomes necessary. Yet, if an alternate landing becomes necessary in this phase e.g. because of sudden airport/runway closure and/or severe weather[253], the cockpit crew will contact both ATC and OCC as to analyze and resolve the situation; this might also encompass flying holding patterns for a limited time as to give the OCC time for adequate solution-finding.

Once the Touchdown Point (TPT) has been reached, the aircraft has landed at the arrival airport. This point in time is referred to as the Actual Time of Arrival (ATA).

- **Taxi-In and Parking**: After having vacated the runway, the cockpit crew taxis the aircraft to its final parking position on the apron and shuts down the engines. No cockpit crew / OCC interaction is allowed during this phase of flight as an ongoing flight operation is officially not finished until the aircraft has been parked and the aircraft's engines are shut down.[254]
- **Post-Flight (FLTD)**: This phase covers all activities which have to be conducted by the cockpit crew, still being on the flight deck, after the aircraft has been parked. This comprises shutting down or resetting aircraft systems to their initial state and documenting aircraft status, flight logs and times, as well as the remaining fuel.

  If the aircraft is used by the same cockpit crew for an additional flight cycle, communication for the purpose of planning the subsequent operation may take place between OCC and cockpit crew during this phase. In this case, all the actions which have already been described in the Pre-Flight (GND) and Pre-Flight (FLTD) phases happen aboard the aircraft as the crew usually does not have enough time to visit the OCC or the airline's airport briefing room; all necessary operational information are either transmitted to the cockpit crew by means of ACARS, CPDLC or SATCOM and – if there is no printer available in the aircraft – provided as paper copies by the responsible ramp agent.

  If the aircraft is not used by the same cockpit crew for an additional flight cycle, the Post-Flight (GND) phase begins.
- **Post-Flight (GND)**: This is last phase of the cockpit crew workflow. It covers all the cockpit crew's activities which have to be conducted when having left the flight deck. This mainly comprises administrative tasks such as filling out technical logs as to ensure that the following crew is fully aware of aircraft status and the Maintenance Control Center (MCC)[255] can initiate appropriate maintenance actions.

  If the cockpit crew has to perform another flight after the preceding one has been finished, a new sequence is initiated and the Pre-Flight (GND) phase starts again.

  Otherwise, if the cockpit crew does not have to perform another flight as, e.g., their duty period is over, the sequence does not begin again.

As this summary shows, the OCC works hand in hand with the cockpit crews when it comes to the conduction of operations; the OCC supplies the cockpit crews with all required infor-

[253] Cp. Chapter 6.1: *Scenario 3 (Severe Weather Conditions)*

[254] Cp. EU-OPS 1, 1.085 and FAR Part 121.542 and ICAO /58/, p. 2

[255] Cp. Subchapter 6.2.2 and Chapter 6.3

mation during all phases of flight, performs disruption management and support them in operational decision-making, if necessary. The following Figure 33 serves to illustrate how OCC / cockpit crew interaction takes place nowadays and combines the conventional OCC workflows having been described in Chapter 6.3 with the cockpit crew workflows having been specified in this Chapter 6.4.

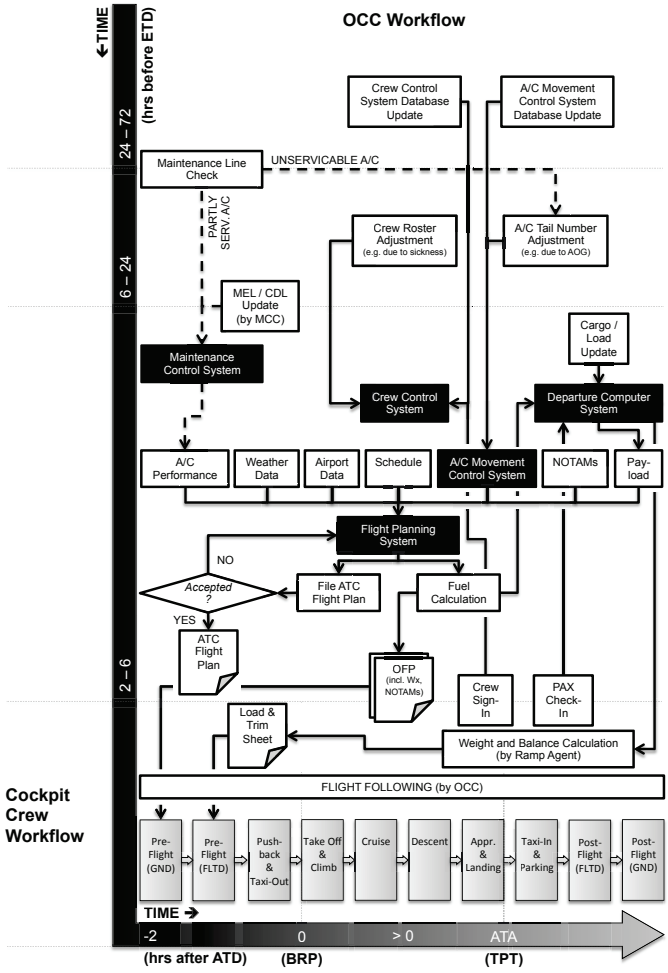


Figure 33: Interaction of OCC-cockpit crew workflows[256]

The vertical axis represents the time left until ETD and refers to the OCC workflow; the horizontal axis serves to depict the chronological sequence of the cockpit crew workflow and, thus, refers to the ATD as it is used to describe another perspective. Since there is a seamless transition of both axes, the intersection point of both axes must not to be seen as the point of origin of a graph describing correlations by means of a mathematical function; Figure 33 rather serves as a visualization of interacting and/or dependent processes. Some of them – but not all – are being conducted either synchronously or linearly. Thus, the complexity and both the partly synchrony and linearity of the regarded workflows do not allow for an universally valid, generic illustration of the processes contains within, but serves to highlight both the interactions and dependencies of OCC as well as cockpit crew workflows.

In summary, the following interactions and dependencies between OCCs and cockpit crews can be identified:

- **OFP and ATC flight plan**: The exchange of OFPs is one main element in the OCC-cockpit crew interaction. It contains all relevant data needed for the conduction of a given flight and is calculated by the OCC's *Flight Dispatch* in order to ensure both

[256] Author's own illustration; based on [Dellal /47/, p. 9 and 18] as well as Figure 32

safe and efficient operations. Once processed by means of the *Flight Planning System*, the OFP is transmitted to the cockpit crew approximately 1-2 hours before ETD.[257] From this point in time, it serves as the pilots' operational road map as it especially defines routes, altitudes, time constraints and fuel quantity.[258]Moreover, the OCC's Flight Dispatch has to ensure that the OFP covers all aspects which are officially filed in the *ATC Flight Plan* of a given flight. This means that, e.g. when a severe navigational change occurs, it has to be ensured that an updated version of the OFP is provided to the cockpit crew timely. When the cockpit crew is no longer able to receive the OFP via a crew login terminal at the airport, it can also be sent to the aircraft by means of ACARS, CPDLC or SATCOM.

- **Load & Trim Sheet**: The *Load & Trim Sheet*, which has already been described in Chapter 6.3, is delivered to the cockpit crew shortly before the aircraft leaves the gate. It shall ensure that the aircraft is loaded properly according to its CG and mass limitations and indicates the cockpit crew how they have to trim the aircraft.[259] This helps to ensure both safe and efficient operations. Thus, the Load & Trim Sheet is only received by the crew when still being in the *Pre-Flight (FLTD) phase*. As it may happen that some passengers do not board the aircraft, the Load & Trim Sheet may be subject to sudden revision by the *Ramp Agent*. This, however, increases the cockpit crew's workload as they have to enter the data provided by the Load & Trim Sheet into the aircraft's Flight Management System (FMS) shortly before take off. It has to be considered that the actual TOW of the aircraft – as provided in the Load & Trim Sheet – has to be consistent with the OFP calculation. If this is not ensured, the OFP is not reliable anymore as the fuel calculation contained therein is not valid. Therefore, the OCC has to be consulted if the TOW shown on the Load & Trim Sheet deviates distinctly from the OFP; in this case, the OFP has to be re-calculated and transmitted to the cockpit crew by the OCC.
- **Flight Following**: *Flight Following* is performed by both the OCC's functional groups *Operations Control and Coordination* as well as *Flight Dispatch* during all phases of flight, but active OCC-cockpit crew interaction happens only when engines are shut down or when the aircraft is at or above FL 100. This kind of interaction shall ensure operational support of the cockpit crew when it comes to unforeseen deviations from the original OFP and ensures the safe and efficient conduct of operations.

As seen from today, this Chapter 6 described how airlines take over operational control by the means of OCCs and identified OCC / cockpit crew workflow phases and interactions. The following Chapter 7 serves to analyze how the ongoing implementation of the ATM initiatives SESAR and NextGen interferes with OCCs.

[257] Cp. Chapter 6.3

[258] The OFP also consists of other kind of information; cp. Chapter 6.3.

[259] Cp. Chapter 6.3

7 AIRLINE OPERATIONS CONTROL CENTERS IN THE FUTURE

Chapter 7 gives an overview of how the ATM initiatives SESAR and NextGen will influence the OCCs' workflows and processes in the future. Therefore, Chapter 7.1 outlines to what extent SESAR and NextGen official project documentations account for the conceptual integration of OCCs into the new ATM environments. On this basis, Chapter 7.2 serves to analyze how the implementation of both ATM initiatives – being very similar to each other, as shown in Chapter 5 – may influence future OCCs, both during the long- and short-term airline planning phases (Subchapters 7.2.1 to 7.2.3).

7.1 OCCS' CONCEPTUAL INTEGRATION INTO SESAR AND NEXTGEN

As described in Chapter 6, every airline is dependent on the effective functioning of its OCC as its employees are responsible for short-term operational planning and the execution of operational control, starting approximately 72 hours before the ETD of a given flight. Thus, the OCC is the part of an airline – together with the airline's individual cockpit crews – which represents it as an airspace user and ATM stakeholder.

Considering this and the fact that the fundamental aim behind all the complex processes necessary to perform modern aviation is to enable airspace users to transport people and/or goods from point A to B, it might seem obvious that the OCC should be regarded as vital to ATM. This applies especially to TBO-based ATM environments as the negotiation of 4DTs is a highly complex, critical process which may not be handled by air traffic controllers and cockpit crews without consulting OCC personnel. This is due to the fact that only the OCC duty manager and OCC employees – not the individual cockpit crews – may access and process all relevant operational information and bear the airline's economical risks resulting from operational decisions. Additionally, it has to be considered that decisions taken may not only affect an individual flight, but also subsequent ones; airborne cockpit crews do neither have the required mental resources nor the necessary training, experience and knowledge to take decisions which do not only concern their own flight's status and/or efficiency, but also the status and/or efficiency of the airline's network operations. Thus, it is essential that OCCs are regarded as an airline's main interface with other ATM stakeholders, both before and while a flight it is conducted, as an OCC's personnel is responsible for managing an airline's entire network operations.

Yet, the importance of OCCs for the operational efficiency of both airlines and the entire ATM is not well respected and conceived in SESAR and NextGen. Both initiatives lack of information on how to integrate OCCs as they strongly foster direct communication between ATC and cockpit crews instead.[260] The analysis of the project documentation of SESAR and NextGen, especially the documents representing the *Concepts of Operations* (ConOps) and the *Master Plans*, make this point obvious. Table 4 gives an overview of the word count of the terms *OCC, AOCC and FOC*[261] in those documents.

	SESAR initiative	**NextGen initiative**
ConOps	• SESAR JU /43/: 21 counts on 145 pages	• JPDO /64/: 11 counts on 153 pages
ATM Master Plan	• SESAR JU /27/: 13 counts on 152 pages	• FAA /63/: 16 counts on 96 pages

Table 4: OCC word count in official SESAR/NextGen documentation[262]

[260] JPDO /82/, p. 8

[261] The terms *AOCC* (Airline Operations Control Center) and *FOC* (Flight Operations Center) equal the term *OCC*.

[262] Author's own illustration

As it can be seen, these terms can only be found very rarely, as measured by the OCCs' importance for the functioning of a modern ATM system relying on TBO and CDM, indicating that the idea of OCC integration is underrepresented.[263] Moreover, all these sources of information are not very rich in content when it comes to OCCs, as stated also during interviews conducted with [Gülcan /54/][264], [Lindner /55/][265], [Güldenberg /56/][266] and [Levi /80/][267]; OCCs are only mentioned casually and indirectly, e.g. when it comes to the specification of how aeronautical and/or operational information (e.g. information on delays or diversions) will be transmitted from ground to cockpit, and the function of today's OCCs as the airlines' main interface with both cockpit crews and ATC entities is confirmed indirectly when reading in between the lines. Yet, there is no specific information given on how both SESAR and NextGen will transform relevant operational workflows or structures when it comes to CDM or 4DT negotiation. Thus, the documents listed in Table 4 have to be regarded as not being useful for a scientific analysis of the conceptual integration of OCCs into SESAR and NextGen as they currently do not provide detailed specifications.

Whilst this circumstance is justifiable as seen from the NextGen implementation timeframe which has a 2025 time horizon, SESAR development shall be finished by the end of 2013 and deployment shall conclude by the end 2020 according to schedule.[268] Therefore, at this point in time, a more detailed concept by far should be available, concerning the integration of OCCs into the future European ATM network. This is necessary since airlines (and other ATM stakeholders) need time to implement required system components, train their staff and adapt process flows accordingly.

But as of today, [SESAR JU /81/] only published some information on the organizational aspects of the integration of OCCs into the future European ATM system by laying down the description of work for the relevant SESAR JU work package *WP 11.1 (Flight and Wing Operation Centers)*. However, this document only serves to specify timeframes, necessary expertise and validation measures of sub-work packages and subordinate tasks, but does not give a specification of how the overall role of the OCC in general will look like once SESAR is fully established. No additional information concerning the general integration of OCCs into the SESAR environment and the resulting outcomes is given by the responsible entity SESAR Joint Undertaking (SJU).[269]

Asked in written form whether there is more WP 11.1 documentation available, two responsible SESAR JU managers, Mr Marc Tenenbaum[270] and Mr Paul Dunkley[271], did not answer at all, even on repeated inquiry.[272] Another inquiry to the SESAR Joint Undertaking Public Relations department concerning the question why there is not a single airspace user represented in the SJU has also not been answered.[273] The question arises, in how far the conceptual

---

[263] Cp. Chapter 5

[264] Mr Ibrahim Gülcan is manager of the Air Berlin OCC in Berlin, Germany.

[265] Mr Hermann Lindner is, on behalf of Air Berlin, responsible for political affairs and contact person for SESAR.

[266] Mr Helge Güldenberg is manager of the Deutsche Lufthansa HUB Operations Center in Munich, Germany.

[267] Mr Dean Levi works for the Advanced Research department of Jeppesen (Denver) and is expert for the integration of OCCs into current and future ATM systems.

[268] Cp. Chapter 3.3 and Subchapter 5.1.4

[269] Cp. Chapter 3.2

[270] Mr Tenenbaum is SESAR Deputy Contribution Manager and manages the EUROCONTROL research and development contribution to the SESAR Joint Undertaking (SJU).

[271] Mr Dunkley is SESAR Joint Undertaking (SJU) Programme Manager and in leading responsibility for the entire WP 11 (WP 11.1: *Flight and Wing Operation Centers* and WP 11.2: *Meteorological Information Services*).

[272] Cp. both Annex 5: Emails to Mr Marc Tenenbaum (SJU) and Annex 6: Emails to Mr Paul Dunkley (SJU)

[273] Cp. Chapter 3.2

integration of OCCs into the SESAR environment has been advanced throughout the last years.

As seen from the NextGen perspective, there is five years more time left to cope with a very similar situation. However, [JPDO /82/] published a report which validates the integration of OCCs into the NextGen environment and gives recommendations for further implementation, aiming at "bringing greater attention and focus to the important role that FOCs should play in the evolution of the Next Generation Air Transportation System (NextGen)".[274] The document lists the following findings currently countervailing the efficient and reasonable conceptual integration of OCCs into the NextGen environment:

- **Finding 1 – Missing overall ATM focus**: The integration of TBO into OCC processes and workflows is currently insufficient as NextGen focuses too strongly on the modernization of ATC instead of the entire ATM environment. Especially the OCCs' role in the entire ATM process – covering not only pre-flight, but also in-flight and post-flight phases – has to be prioritized and specified more explicitly. Thus, [JPDO /82/, p. 3] states that "Trajectory-Based Operations (TBO), the key operating paradigm of NextGen, lacks full consideration of FOC decision processes". Furthermore, NextGen has a strong focus on individual flights and does not encompass TBO in a complex ATM environment with multiple aircraft sufficiently.[275]

- **Finding 2 – Missing continuity in CDM process**: An analysis of available NextGen project documentation conducted by the JPDO showed that the OCCs' time horizon for strategic planning is not sufficient for the complex CDM processes fostered by NextGen. It simply does not encompass the time an airline needs for strategic planning, as defined in Chapter 6.1. Therefore, it can be reasoned that this circumstance will lead to a lack of continuity in the process of CDM between affected stakeholders as the negotiation of 4DTs is done weeks before the OCC – being responsible for the adherence to the negotiated 4DTs – takes over operational control of the last 72 hours before ETD. Thus, the OCCs' responsible personnel will have to adhere to 4DTs which they did not negotiate themselves and which cannot be individually adapted during the last 72 hours before ETD because of minor reasons like improving operational efficiency as this, again, would necessitate a complex, time-consuming CDM process with all affected stakeholders.

- **Finding 3 – Missing rules for ATM resource allocation**: ATM resources are limited as their acquisition, operation and maintenance is expensive and binds financial resources in the long term. This is why available ATM resources have to be rationed in a fair, flexible and comprehensible way. Moreover, it has to be ensured that the benefit of the overall ATM system – meaning an optimal usage of existing resources – has always a higher priority than the one of individual stakeholders. This is currently not ensured as it can be realized by analyzing the official NextGen documentation.[276] Thus, as seen from today, "it remains unclear what the right rationing mechanisms are when [ATM] resources (e.g., airport and airspace capacity) become constrained, or how NextGen prioritizes flights".[277]

- **Finding 4 – Missing rules for CDM data sharing**: There are currently no binding rules defined how the sharing of both critical and uncritical data needed for CDM shall be conducted in the intended SWIM environment.[278] Yet, data security is extremely

[274] JPDO /82/, p. 3

[275] JPDO /82/, p. 8

[276] JPDO /82/, p. 10

[277] JPDO /82/, p. 3

[278] JPDO /82/, p. 11

crucial as all stakeholders will be forced by law to share huge amounts of data which allow for the analysis of their company secrets. E.g., if 4DTs can be accessed by competing airspace users, they become able to draw conclusions on the Cost Indices (CI) of their competitors. This, in return, may bring them a competitive advantage. Therefore, it has to be strictly defined who may access which information at which point in time by which means. This goes far beyond the question of which stakeholders get read and/or write access as it also has to be individually specified how and for which purposes the accessed data may be processed and used. Moreover, it has to be ensured that the observing of these rules and data security in general are constantly monitored and analyzed.

In order to ensure that the stakeholders' technological and financial risks accompanying the implementation of such a huge initiative can be mitigated as best as possible, [JPDO /82/] recommends resolving the OCC-related findings described above. This shall guarantee that NextGen becomes successful as the filling of the identified gaps is seen as a possibility for course correction since "failure to recognize the evolving importance of the FOC will limit NextGen to tactical, individual flight-focused, sub-optimal operations".[279] This scenario, in the end, would not only have a negative effect on the efficiency of individual airlines, but also on the efficiency of the overall NextGen environment; this is due to the fact that many – more or less uncritical – insufficiencies resulting from the sub-optimal usage of existing ATM resources during single operations would add up to critical insufficiencies affecting major parts of the entire ATM network.

In summary, the JPDO has recognized that there is a lack of OCC-related specifications within NextGen; they try to strengthen the OCCs' role in the NextGen environment by validating existing concepts as an expanded OCC involvement in "planning and development processes [will help achieve] broader system benefits and [ensure] a proper focus is placed on transforming the air transportation system".[280]

The SJU, however, does not define the OCCs' role in the future SESAR environment sufficiently as there is no validation report published so far. Thus, a performance benchmark and the improvement of existing concepts is not possible, resulting in a state of uncertainty which does not only affect OCC operators, but also all other SESAR stakeholders. This is due to the fact that the proper, efficient integration of OCCs into the future ATM networks must be considered as being essential for the overall success of both ATM initiatives, following the reasons given above. According to the definition of SESAR project phases[281], necessary development work packages should be finished by the end of 2013 as deployment of developed technologies and workflows is scheduled to start in 2014. It remains to be seen in how far the missing specifications for OCC integration will endanger the overall success of SESAR.

7.2 ANALYSIS OF THE INFLUENCE OF SESAR AND NEXTGEN ON OCC WORKFLOWS AND INTERACTIONS

Chapter 6 served to depict the integration of OCCs into today's airline planning processes and current OCC workflow interactions. As stated in the previous Chapter 7.1, currently both the SESAR and NextGen project documentations do not define the future roll and workflows of OCCs in the intended TBO environments sufficiently. Yet, it can be asserted that recent OCC workflows as well as OCC-cockpit crew interactions – as illustrated in Figure 33 (p. 68) – will no more be valid when TBO and CDM are conducted throughout the entire ATM network. This has the following reasons:

[279] JPDO /82/, p. 4

[280] JPDO /82/, p. 3

[281] Cp. Chapter 3.3

- **Reason 1 – Lack of operational information during 4DT negotiation**: The definite routing of a flight, represented by its RBT, will be defined weeks or even months before the flight actually takes place when the RBT is negotiated. This happens during the phase of strategic airline planning.[282] However, relevant operational information will not be available at this point in time; this encompasses particularly reliable weather forecasts[283], NOTAMs (especially with respect to airspace and airport congestions and closures) as well as both crew and aircraft operational status[284]. Moreover, the TOW of the assigned aircraft is unclear as the final payload is unknown during strategic planning.[285] This makes the exact calculation of the optimum cruise flight level (FL) impossible. Therefore, the final TOW has to be estimated during 4DT negotiation, which results in fuel inefficiencies as airlines will be forced to fly according to suboptimal RBTs which do not consider – during all phases of flight – the actual aircraft weight correctly. Thus, the inefficiencies resulting from the lack of necessary operational information in the long-term planning phase – which is currently not under control of the OCC, as specified in Chapter 6.1 – will have to be resolved in the short-term planning phase which the OCC is responsible for. This makes a change in OCC processes necessary and increases the workload of OCC personnel as they will then have to cope with both airline-intern and complex NOP provisions in a limited timeframe, as they will have to perform short-term RBT adjustment in order to ensure operational efficiency.

- **Reason 2 – RBTs to replace ATC flight plans**: There will be no more ATC flight plans filed, as 4DTs – once negotiated by means of CDM – will be added to a Network Operations Plan (NOP)[286] which represents the reference flight plan when it comes to managing the entirety of all the ATM network's RBTs.[287] This, in direct return, means that an OFP will no more be created according to an approved ATC flight plan, but according to a RBT being stored in the NOP. But even though the RBT – containing, amongst others, all waypoints, step climbs/descends and corresponding waypoint altitudes – will be negotiated weeks or even months before the actual flight takes place, the OFP will have to be created when reliable operational information (cp. *Reason 1*) is available, which is during the last 72 hours before ETD. If it comes to a situation where an already negotiated RBT has to be adjusted because of operational reasons during this pre-flight period, a NOP query has to be conducted by the OCC as to analyze in how far newly required ATM resources (especially airways and airport slots) are still available. Once a RBT adjustment has been cleared, both the OFP and the NOP have to be edited accordingly as to guarantee that both operational safety and efficiency are given at every point in time. Although it is not defined yet which ATM stakeholder(s) will be responsible for short-term NOP editing, it would make sense to assign this tasks to the ATC entities as they are also responsible for ultimately clearing RBT operations and ensuring aircraft separation minima during all phases of flight.

- **Reason 3 – Airlines' influence on short-term decision-making will decrease:** The OCC short-term decision-making processes will no more be based solely on OCC-cockpit crew coordination with subsequent ATC notification and clearance-obtaining

[282] Cp. Chapter 6.1

[283] As of today, weather conditions cannot be forecasted reliably for more than several days.

[284] At the point in time when the 4DTs for a given flight is negotiated, it cannot be foreseen, e.g., how much and which employees will be sick or how much and which aircraft will be inoperable. Moreover, delays may not be accounted for yet.

[285] This is due to the fact that ticket sale is not finished yet and passenger no-shows may not be predicted accordingly. Additionally, belly load may not always be considered weeks in advance.

[286] Cp. Subchapters 3.4.1, 3.4.3 and 5.1.2

[287] A negotiated 4DT is referred to as Reference Business Trajectory (RBT); cp. Subchapter 3.4.1

as the change of RBTs is subject to CDM between all affected stakeholders, e.g. other airspace users, ground handlers and airports. Thus, because of the increased number of involved decision-makers, short-term operational decision-making will become by far more complex, especially in situations where several or all airspace users are affected by temporary airport and/or airspace closure, as exemplarily described in Chapter 6.1 (*Scenario 3: Severe Weather Conditions*). Therefore, as both time for in-flight decision-making and human performance are limited according to the given situation, automation of CDM processes by means of digital Decision Support Tools (DST) will become inevitable.[288] This means that the variety of possible solutions to occurring disruptions will be finite as the DST – unlike human beings – will not be able to cope with highly complex, unknown situations adequately. This, however, will cause a situation where the airlines' influence on operational decision-making will generally decrease, as OCCs will only have time to choose between pre-defined CDM standard solutions and will have to rely on DST as to be able to respond to the other affected ATM stakeholders' proposals in time.

In addition to DST, short-term bidding tools will be used as to enable airspace users to bid for required ATM resources when it comes to both pre- and in-flight RBT adjustment. This bidding process, being based on the principle of price determination according to supply and demand, will serve the optimal usage of existing ATM resources; yet, it will also increase OCC workload as the short-term resource bidding will require OCCs to perform case-specific cost-benefit analyses in a limited timeframe. As time for both pre- and in-flight resource bidding is limited, it may happen that OCCs will not be able to successfully bid for required ATM resources in time; if such a case occurs, affected OCCs will no longer be able to participate in the CDM process as a solution has to be found instantly in order to avoid flight cancellation or diversion; therefore, some kind of by-pass to the short-term bidding process is necessary. This means that affected airspace users must have the possibility to request priority handling from ATC, which – once granted after having verified that priority handling is legitimate – will act as kind of troubleshooter by taking over responsibility for solution-finding in close cooperation with the airspace users when bidding has not been successful and time is running short.[289] Yet, the solution which will be found in such a situation will most-likely not be the most cost-efficient, but only a suitable one as ATC may not account for individual airlines' cost-efficiency, but only for the safety and efficiency of the overall ATM environment.

- **Reason 4 – Shift in focus between OCC-cockpit crew interaction**: The way OCCs and cockpit crews cooperate will change as NextGen strongly focuses on ATC-cockpit crew interaction when it comes to operational decision-making, according to [JPDO /82/, p. 8]. Regarding SESAR, this statement can neither be verified nor falsified as there is currently no detailed concept, describing the OCC integration into the SESAR environment, available.[290]

  Yet, [EUROCONTROL /28/, p. 35] specifies that in-flight RBT adjustment will be handled directly between ATC and cockpit crews as ATC will assume that the change request has been discussed and agreed between cockpit crews and OCCs in advance. This statement serves to assume that also SESAR will rather rely on a direct ATC-cockpit crew interaction instead of an indirect, three-way ATC-OCC/OCC-cockpit crew/cockpit crew-ATC interaction. However, it is not likely that the OCCs' *Flight Following* function[291] will become dispensable for two main reasons: on the one hand,

[288] Cp. Subchapter 5.1.3

[289] Remark: Detailed rules which legitimate priority handling will have to be specified, both for pre- and in-flight situations.

[290] Cp. Chapter 7.1

[291] Cp. Subchapter 6.2.1

the international binding provision [ICAO /48/, p. 4-16] prescribes that "flight dispatchers […] shall […] furnish the pilot-in-command while in flight, by appropriate means, with information which may be necessary for the safe conduct of the flight"; it is unlikely that this provision will be changed as ensuring safety is always more important than ensuring operational efficiency. On the other hand, a cockpit crew is only aware of their own flight's status, not of the ones of other flights of their airline. Thus, they are unable to assess their airline's current overall operational status sufficiently and cannot make appropriate decisions concerning total airline efficiency. Therefore, the in-flight OCC-cockpit crew interaction by means of *Flight Following* must remain one of the most important OCC functions, as "with proper FOC-traffic management interaction many situations (e.g., airspace congestion) could be avoided, obviating the need for [ATC] controller intervention".[292]

Chapter 7.2 reasoned how OCCs will be influenced by SESAR and NextGen. The following Subchapters identify possible outcomes on OCCs as schemes for the integration of OCCs into the airline planning process (Subchapter 7.2.1) and future OCC-cockpit crew interactions, both during the pre- and in-flight phases (Subchapters 7.2.2 and 7.2.3), are evolved.

7.2.1 POSSIBLE OUTCOMES ON OCC INTEGRATION INTO AIRLINE PLANNING PROCESSES

Combining *Reason 1* with *Reason 2* and following [JPDO /82/]'s *Finding 2*, it has to be asserted that future OCCs should cover a time horizon of several weeks, beginning with the initial planning and negotiation of a 4DT and ending when the flight has been conducted.[293] In this case, the interaction of OCCs with the airline's other departments responsible for *Strategic Planning*[294] will alter significantly, as illustrated in Figure 34.

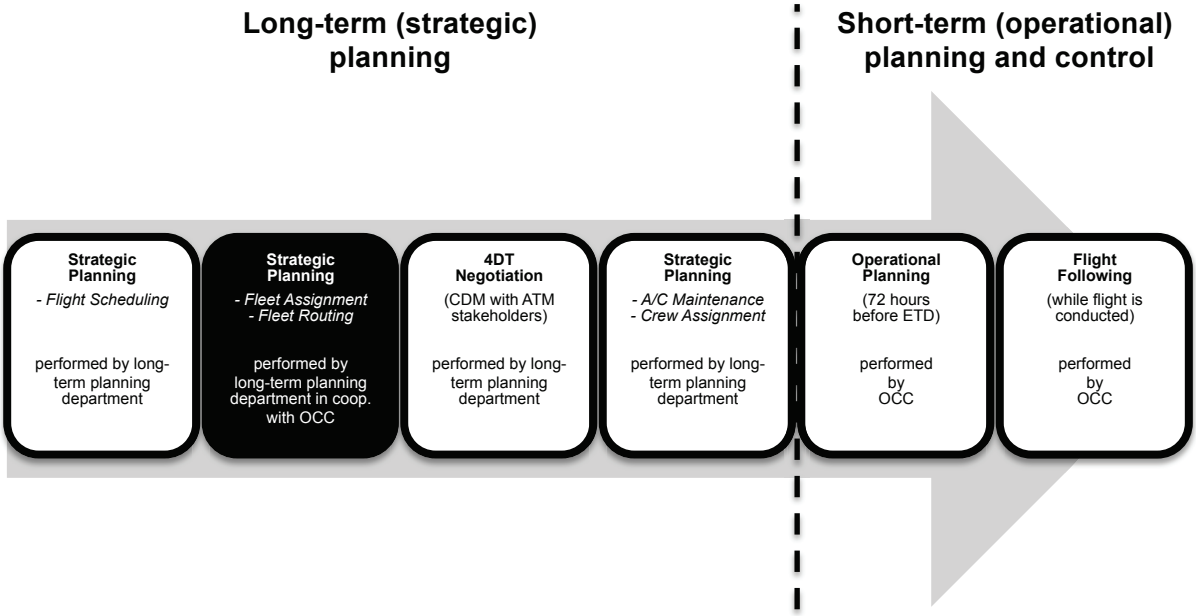


Figure 34: Future OCC involvement in the planning process of airlines[295]

This means that future OCCs will have to cope with the tasks associated with *Strategic Planning* – fleet assignment and routing (highlighted in black) – since the results of these plan-

[292] JPDO /82/, p. 8

[293] Cp. Chapter 7.1

[294] Cp. Chapter 6.1

[295] Author's own illustration

ning tasks must fit to the negotiated 4DTs. This results from the fact that every aircraft has its own performance, especially when it comes to the climb and descent flight phases.

As to give an example, there will be aircraft within an airline's fleet which may not climb as efficiently as others do, which may result in the problem that a climb procedure specified within a flight's RBT cannot be followed as aircraft climb performance is insufficient. Cruise performance is also relevant as aircraft have different optimal and maximal cruise speeds; it must be ensured that the cruise speed assumed during the planning and negotiation of a RBT will be achievable during flight.

Therefore, the highlighted long-term *Strategic Planning* tasks must be performed by the airline's responsible departments in close cooperation with the OCC as to minimize, during the phase of strategic planning, the number of situations where short-term RBT adjustment becomes necessary during the last 72 hours before ETD. However, it will be the individual airline's decision how to ensure this continuity between strategic and operational planning; it is not necessary that the process of regular 4DT negotiation is integrated into OCC workflows, but it should be ensured that the OCC is represented in the strategic planning department as to take influence in the 4DT negotiation process.

This shall ensure that short-term RBT adjustment becomes only necessary if unforeseen disruptions, e.g. resulting from severe weather, airport/airspace closure or aircraft inoperability, occur; thus, the need for time-consuming and expensive RBT adjustment by means of short-term bidding – resulting from missing knowledge on operational procedures and aircraft performance during 4DT negotiation – can be minimized to an economically justifiable extent.

7.2.2 POSSIBLE OUTCOMES ON PRE-FLIGHT OCC WORKFLOWS AND OCC-COCKPIT CREW INTERACTIONS

OCCs and their interactions with other ATM stakeholders will not only be affected by SESAR and NextGen during the long-term *Strategic Planning* phases, but also during the *Short-term Planning* phase covering the last 72 hours before ETD. Considering the *Reasons 1* to *3* given in Chapter 7.2 and emphasizing the fact that both SESAR and NextGen lack of detailed information concerning future OCC workflows[296], Figure 35 (p. 78) serves to give an idea of how a scheme for future pre-flight OCC-cockpit crew workflow interaction may look like in comparison to the current one (previously depicted in Figure 33, p. 68). In this context, the items marked in grey represent functions, tasks or necessary data input which deviate from current OCC workflows. All other OCC depicted workflows will not be influenced by SESAR or NextGen provisions.

By comparing both schemes, it becomes obvious that future pre-flight OCC workflows will be mainly influenced by the NOP which contains the RBTs for each individual flight[297]. The therein stored trajectory information will be used as reference for both fuel calculation and the creation of the OFP. Yet, this can only happen if the formerly negotiated RBT is still viable[298]; this means that there must not be operational reason(s) – e.g. adverse weather, aircraft inoperability or insufficient aircraft performance – which argue against the usage of this negotiated RBT.

[296] Cp. Chapter 7.1

[297] Corresponding item in Figure 35 (left part): [*NOP (RBT)*]

[298] Corresponding item in Figure 35 (left part): [*RBT viable?*]

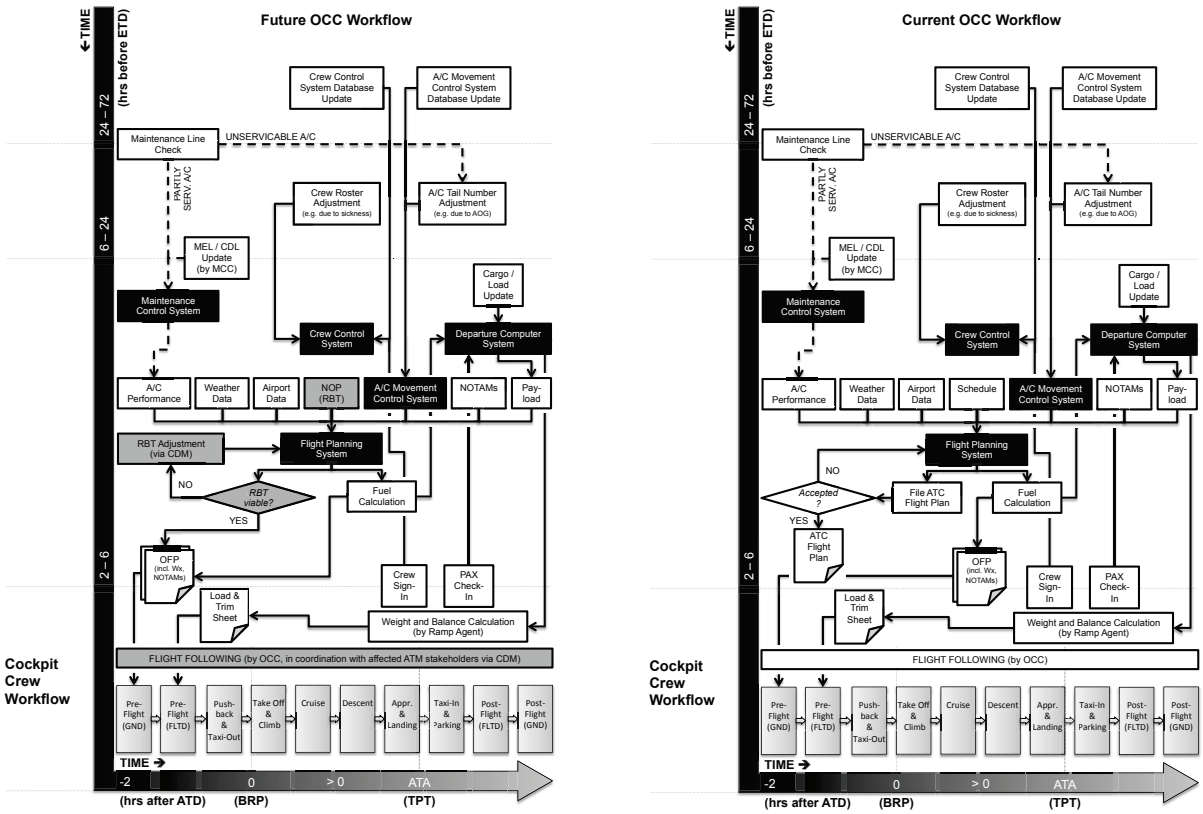


Figure 35: Future and current OCC-cockpit crew workflow interaction[299]

If a RBT is not viable any more, it has to be adjusted by means of CDM between all affected stakeholders.[300] The scheme shown in Figure 36 illustrates how future pre-flight RBT adjustment may possibly look like once the SESAR and NextGen key features TBO, SWIM and CDM will have been put into operation.

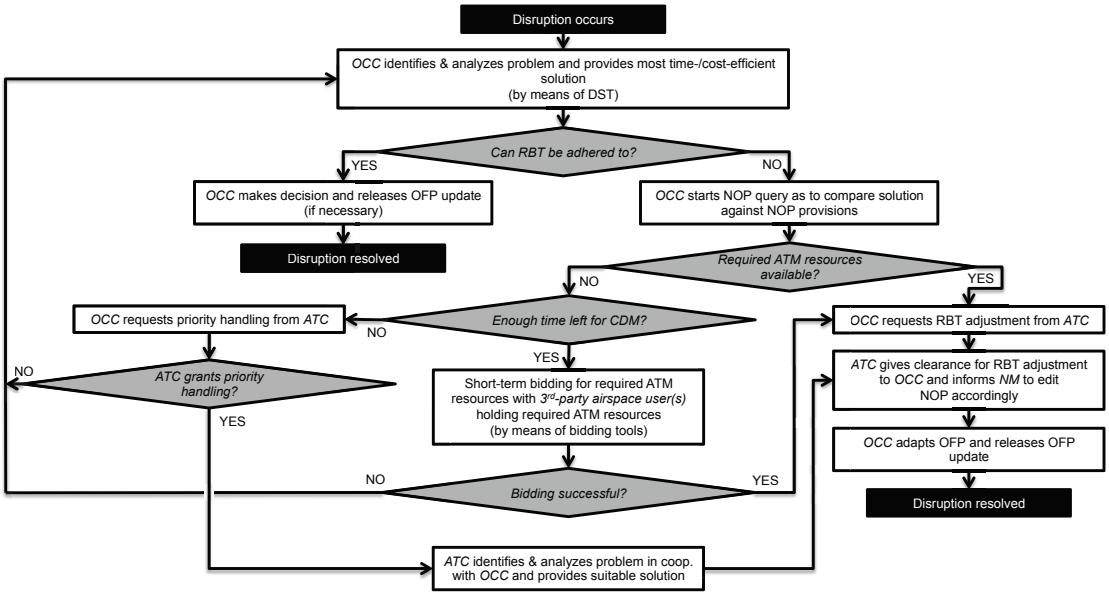


Figure 36: Pre-flight RBT adjustment by means of CDM[301]

[299] Author's own illustration; as to enhance reading comfort, HD versions are provided in Annex 7.

[300] Corresponding item in Figure 35 (left part): [*RBT Adjustment (via CDM)*]

[301] Author's own illustration; as to enhance reading comfort, a HD version of this scheme is provided in Annex 8.

As to exemplarily explain this iterative scheme[302], *Scenario 1 (ENG inop)*, which has already been described in Chapter 6.1 (p. 53), will be applied in the following:

[i=0] After the *disruption occurred* (= ENG has to be substituted after birdstrike, originally assigned aircraft therefore not operable in time), the OCC *identifies and analyzes the problem* by means of Decision Support Tools (DST) which assist the OCC's personnel in analyzing the situation and provide a pre-defined set of standardized decisions.

In this case, the *most time-/cost-efficient solution* is to substitute the originally assigned A380-800 by a B747-400, exchange cockpit crew accordingly and increase cruise Mach number from 0.85 to 0.87. But as the B747-400 has other aircraft performance characteristics than the A380-800 and the flight is moreover delayed by 55 minutes according to the originally scheduled Off Block Time (OBT), *the negotiated RBT can no longer be adhered to*, even though the OCC decides to adhere to the original routing of the flight *[= CASE NO]*.[303] This is due to the fact that new airport slots for both the departure and the arrival airport as well as other waypoint overfly times have to be negotiated. Once a new 4DT has been calculated by the OCC, the OCC has to *initiate a NOP query* in order to compare whether their preferred solution (= new 4DT) fits to the other airspace users' intended operations stored within the NOP (= other stakeholders' RBTs) and does not *require ATM resources* (= airport and airway slots) *already allocated* to other flight operations.

[CASE YES] *If the required ATM resources are available*, the OCC requests an adjustment of the original RBT from ATC; once having cross-checked that the requested ATM resources are really available, the *ATC clears the RBT adjustment to the OCC and informs the Network Manager (NM)*[304] *to edit the NOP accordingly*. It is important that an independent authority is responsible for NOP editing as both the safety and efficiency of the conducted operations can only be guaranteed if the NOP contains only the latest (up-to-date) RBT information and, thus, remains valid and reliable. After having obtained the clearance for RBT adjustment, the *OCC adapts the OFP and releases an OFP update to the cockpit crew*. Consequently, the *disruption is resolved*;

[CASE NO] However, *if the required ATM resources are not (all) available,* the *short-term bidding* for the unavailable ATM resources will have to be conducted, *if there is enough time left for CDM*.[305] In the given scenario, only the arrival airport slot is subject to short-term bidding as the given overfly times, both the departure airport slot and all waypoints slots are not allocated yet. Once the bidding is over, the *OCC was either successful or not*:

[CASE YES] In case the *bidding was successful* (= required arrival airport slot obtained), the *disruption is resolved* as the RBT adjustment can take place according to the sub-process which has already been described in the next-to-last paragraph;

[CASE NO] If the *bidding was not successful* (= required arrival airport slot not obtained), the process of *problem analysis and solution-finding* starts again (= new iteration, *[i=i+1]*). This happens as long as the disruption has not been resolved and there are other suitable solutions to the problem available. Yet, at a given point in time *[i=0+x, x ∈ IN\{0}]*, there will *no more time be left for CDM* and ATM resource bidding as the intended ETD of the flight comes close; in this case, the OCC will *re-*

[302] First iteration: i=0; subsequent iteration: i=i+1

[303] The trivial case (= RBT can be adhered to without RBT adjustment) is not considered in the following; an example for such a case is that a sick crew member must be substituted; this makes short-term OCC troubleshooting mandatory, but does not necessarily result in RBT adjustment as long as the disruption does not endanger the scheduled OBT of the intended flight operation.

[304] Remark: ATC has either to inform the NM or any other entity officially assign for operational NOP editing; cp. further below on this page.

[305] Cp. Chapter 7.2

quest priority handling from ATC as to avoid flight cancellation. Once granted, the ATC will *assist the OCC in identifying and analyzing the problem* until a suitable, but not necessarily optimal solution (= new RBT) has been found. This new RBT must then be officially *cleared by the ATC*; after having obtained the clearance for RBT adjustment, the *OCC adapts the OFP and releases an OFP update to the cockpit crew*. Consequently, the *disruption is resolved*.

Regarding the scheme for pre-flight RBT adjustment depicted above, it is obvious that the corresponding decision-making process does actually not involve cockpit crews directly. This is because cockpit crews are either not on duty at this point in time or are conducting another flight which requires their full, unshared attention and does not allow for participating in the planning of the subsequent flight. Therefore, during this phase, cockpit crews will only be informed when there is an OFP update available, but will in general not be consulted when it comes to RBT adjustment unless they already received a valid OFP in the *Pre-Flight (GND)* or *Pre-Flight (FLTD)* phase[306] and are actively preparing the flight; in this case, the OCC personnel will inform the affected cockpit crew that RBT adjustment becomes necessary and may try to involve them in the solution-finding process, forasmuch as practicable.

Yet, there are some unsolved questions concerning pre-flight RBT adjustment: First of all, as time for operational decision-making is limited, it will have to be specified until which point in time CDM as well as ATM resource bidding must be conducted before an airspace user may request priority handling from ATC; Moreover, it is unclear who or which entity will be made responsible for operational NOP editing. Regarding current EU provisions given in Reg. (EU) No. 677/2011, it is defined that the Network Manager "shall ensure the coherence of the Network Operations Plan" as to ensure NOP reliability.[307] [308] This, however, does not mean that the Network Manager may not place the responsibility of operational NOP editing on ATC entities, for instance. As NextGen currently does not provided respective NOP specifications yet, it is unclear who or which entity will be officially responsible for NOP editing within the NextGen environment. Finally, it will have to be ensured by adequate measures that requesting priority handling from ATC cannot be misused as to avoid expenses, e.g. resulting from short-term ATM resource bidding.[309] In this context, it is also unclear how SESAR and NextGen will handle simultaneous priority handling requests as there are currently no specific rules for flight prioritization and ATM resource allocation published or even validated for both SESAR and NextGen.[310]

While Subchapter 7.2.2 outlined the possible influences on future pre-flight OCC workflows and cockpit-crew interactions, the following Subchapter 7.2.3 serves to do the same for in-flight situations.

7.2.3 POSSIBLE OUTCOMES ON IN-FLIGHT OCC WORKFLOWS AND OCC-COCKPIT CREW INTERACTIONS

The key features TBO, SWIM and CDM, as fostered by both SESAR and NextGen, will also influence in-flight OCC workflows as well as the interaction between OCCs and cockpit crews during flight, as specified in *Reason 4*.[311]

The operational control of a given flight is managed by the OCC's *Flight Following* department.[312] Their responsibility begins as soon as the *Pre-Flight (GND)* or *Pre-Flight (FLTD)*

[306] Cp. Chapter 6.4 as well as Figure 35 (p. 78)

[307] European Union /45/, p. L 185/6

[308] Cp. Subchapter 3.4.3

[309] Cp. Footnote 289

[310] Cp. Chapter 7.1

[311] Cp. Chapter 7.2

phase – dependent on whether the cockpit crew has already conducted a flight cycle with the same aircraft in advance or not – of a given flight takes place and ends at that point in time when this flight has been finished, which is – dependent from whether the cockpit crew conducts another flight with the same aircraft or not – represented by the *Post-Flight (FLTD)* or the *Post-Flight (GND)* phase of this flight. During that period, the *Flight Following* department has to ensure by adequate measures that the given flight can be conducted in a safe and efficient way; this especially means that *Flight Following* is responsible for in-flight disruption management on behalf of the airline, in order to mitigate the operational and financial outcomes of disruptions. Hence, *Flight Following* has to perform in-flight RBT adjustment if the operational situation makes this necessary.

However, regarding in-flight OCC workflows corresponding with the OCCs' *Flight Following* function, it must be asserted that – from a scientific point of view – there are currently not enough binding provisions provided by both SESAR and NextGen.[313] Nevertheless, following the argumentation of *Reasons 3* and *4* given in Chapter 7.2, it can be stated that future OCC-cockpit crew interaction will be – to an yet undefined extent – influenced by the provision of performing CDM with other ATM stakeholders and by an intensified ATC-cockpit crew interaction. Yet, no reliable statement can be made in how far the OCC-cockpit crew interaction will be impaired by this as both SESAR and NextGen do not validate or even specify this topic. Moreover, it also remains unclear to what extent the fostered shift towards an intensified ATC-cockpit crew interaction as discussed in *Reason 4*[314] will impact current OCC-cockpit crew interaction in the future.

Therefore, Figure 37 serves to give an idea of RBT adjustment may be handled in the future by means of CDM between the involved stakeholders *Flight Following*, *Network Manager (NM)*, *ATC* and *Cockpit Crew* and has to be regarded as proposal for managing in-flight CDM in both the SESAR and NextGen environments.

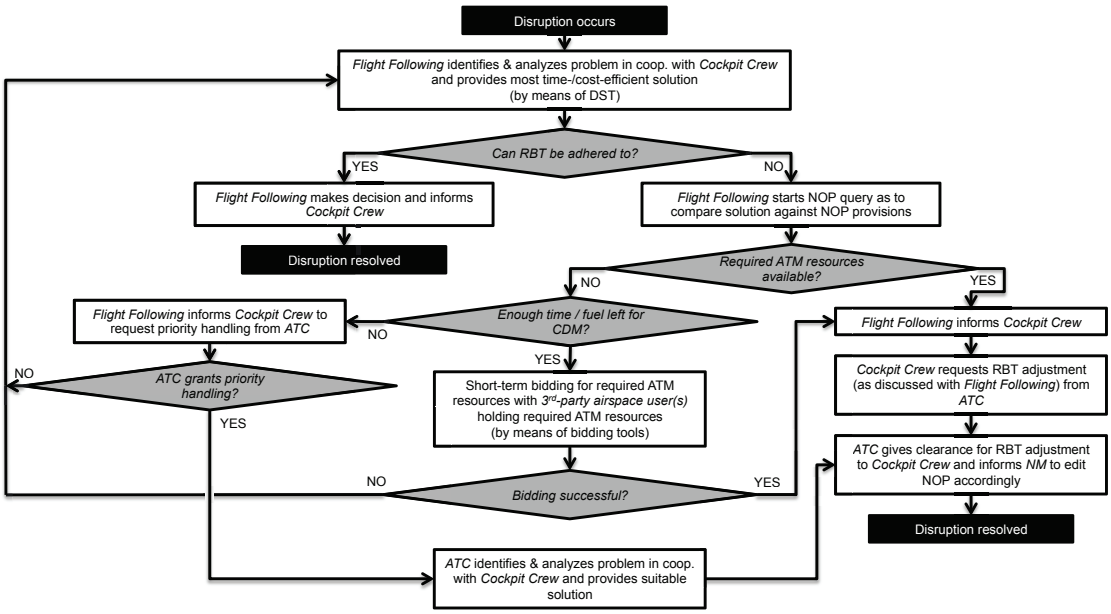


Figure 37: In-flight RBT adjustment by means of CDM[315]

[312] Cp. Subchapter 6.2.1

[313] Cp. Chapter 7.1

[314] Cp. Chapter 7.2

[315] Author's own illustration; as to enhance reading comfort, a HD version of this scheme is provided in Annex 9.

In order to exemplarily explain this iterative scheme[316], *Scenario 3 (Severe Weather Conditions)*, which has already been described in Chapter 6.1 (p. 54), will be applied in the following:

[i=0] After the *disruption occurred* (= thunderstorm activity at original arrival airport KSLC, aerodrome closed for 60 minutes), the OCC *identifies and analyzes the problem* by means of Decision Support Tools (DST) which assist the OCC's personnel in analyzing the situation and provide a pre-defined set of standardized decisions.

As the cockpit crew did not have information on the possible upcoming of a thunderstorm and had no other reason to order any extra fuel, it is not possible to fly holding patterns for any longer than 45 minutes before the reserve fuel is fully depleted[317]; as to avoid fuel shortage and an emergency landing, the solely suitable solution (= *most time-/cost-efficient solution*) is to approach an alternate airport. This means that the *negotiated RBT cannot be adhered* to as a complete new routing and a slot at the alternate airport have to be used *[= CASE NO].* Therefore, *Flight Following starts a NOP query* as to analyze whether their preferred solution (= new 4DT) fits to the other airspace users' intended operations stored within the NOP (= other stakeholders' RBTs) and does not *require ATM resources* (= airport and airway slots) *already allocated* to other flight operations.

[CASE YES] *If the required ATM resources are available*, the OCC informs the *cockpit crew* to request an adjustment of the original RBT from ATC; once having cross-checked that the requested ATM resources are really available, the *ATC clears the RBT adjustment to the cockpit crew and informs the Network Manager (NM) to edit the NOP accordingly*.[318] After having obtained the clearance for RBT adjustment, the *cockpit crew* enters this new RBT into their FMS and the *disruption is resolved*;[319]

[CASE NO] In case the *required ATM resources are not available,* the *short-term bidding* for the unavailable ATM resources will have to be conducted, *if there is enough time left for in-flight CDM*.[320] In the given scenario, the cockpit crew initiates a holding pattern after having obtained ATC clearance and waits until further RBT clearance.[321] In the meantime, the OCC tries to bid for a slot at the preferred alternate airport and all waypoints laying on the route between the current aircraft position and the alternate airport. Once the bidding is over, the *OCC was either successful or not*:

[CASE YES] In case the *bidding was successful* (= required alternate airport and waypoint slots obtained), the *disruption is resolved* as the RBT adjustment can take place according to the sub-process which has already been described in the next-to-last paragraph;

[CASE NO] If the *bidding was not successful* (= required alternate airport and waypoint slots not obtained), the process of *problem analysis and solution-finding* starts

[316] First iteration: i=0; subsequent iteration: i=i+1

[317] For the given scenario, cp. provisions given in FAR 121.639 (Fuel Supply Domestic Operations) and FAR 121.645 (Fuel Supply Flag Operations).

[318] Remark: As also stated in Subchapter 7.2.2, it is important that the NOP contains only the latest (up-to-date) RBT information and, thus, remains valid and reliable. Therefore, an independent authority must be responsible for operational NOP editing as to ensure the safety and efficiency of all conducted operations. Therefore, ATC has either to inform the NM or any other entity officially assign for operational NOP editing.

[319] Remark: Of course, the chosen and solely suitable solution (= approach alternate airport) to the original disruption (=thunderstorm activity at original arrival airport) will be followed by subsequent disruptions as the passengers, the flight crew as well as the aircraft itself did not reach their originally intended destination in time.

[320] Cp. Chapter 7.2

[321] Remark: At this point in time (i=0), the described scenario does not represent an emergency or an emergency-close situation as there is reserve fuel for 45 minutes left. Therefore, ATC priority handling cannot be requested yet.

again (= new iteration, *[i=i+1]*). This happens as long as the disruption has not been resolved and there are other suitable solutions to the problem available. Yet, in the given scenario, there are no other solutions than to approach a suitable alternate airport within the range of the aircraft; but as there are several other airspace users trying to get the same alternate airport slots in order to be able to initiate their own diversions, it may happen that the Flight Following department does not obtain the required ATM resources, even over several iterations.

At a given point in time *[i=0+x, x ∈ IN\{0}]*, there will be *no more time left for CDM* and ATM resource bidding as reserve fuel depletes while the aircraft performs holding patterns; in this case, the OCC will *request priority handling from ATC* as to avoid an emergency situation. Once granted, the ATC takes over the Flight Following's role in troubleshooting and *assists the cockpit crew in identifying and analyzing the problem* until a suitable, but not necessarily optimal solution (= new RBT to alternate airport) has been found. This new RBT must then be officially *cleared by the ATC*; after having obtained the clearance for RBT adjustment, the *cockpit crew* enters this new RBT into their FMS and the *disruption is resolved*.[322]

Comparing this scheme of in-flight RBT adjustment to that of pre-flight RBT adjustment described in Subchapter 7.2.2, it becomes obvious that the former one considers cockpit crews more strongly when it comes to operational decision-making since they are expected to participate in solution-finding if in-flight RBT adjustment becomes necessary, as stipulated by both SESAR and NextGen.[323] Yet, the main part of the disruption management process, especially the solution-finding and ATM resource bidding, is conducted in the background by the OCC's Flight Following; this is due to the fact that cockpit crews do neither have the required mental capacities nor the knowledge and information necessary for in-flight CDM with all affected ATM stakeholders in complex situations like the once specified in *Scenario 3 (Severe Weather Conditions)*. Therefore, when it comes to the actual process of requesting a RBT adjustment for ATC, the cockpit crews will have to rely on the Flight Following's proposed solution as the entire process of ATM resource re-allocation – consisting of the subprocesses NOP query and ATM resource bidding – is done without cockpit crew involvement.

Analyzing the above shown scenario and in addition to the problems occurring during pre-flight RBT adjustment – especially missing provisions for NOP editing and the prioritization of individual flights requiring the same resources simultaneously –, there are some gaps which can be identified by analyzing the above shown scenario: At first, there has to be some kind of short-term reservation system for the required ATM resources during the in-flight RBT adjustment process: as the thunderstorm activity does not only affect one single airspace user but also all others in the regarded area, it has to be considered that there will be several airspace users conducting RBT adjustment at the same time. This means that unallocated ATM resources may be allocated only some seconds afterwards. Therefore, after having checked that the *required ATM resource(s) are still available*, it must be possible to reserve such resource(s) for a limited time as to be able to get adequate ATC clearance for RBT adjustment before the required ATM resource(s) ha(s/ve) been allocated to another flight operation. The usage of such a reservation system would also make sense for pre-flight RBT adjustment, as the same problem might occur during the operational planning phase. Yet, unlike a situation where in-flight RBT adjustment becomes necessary, the safe conduct of operations would not be endangered without such a system during this phase.

Moreover, it will have to be specified how much time CDM may take during in-flight RBT adjustment before priority handling can be granted by ATC. If there is no standardized time frame defined, ATC may not always be able to prepare for taking over responsibility in the

[322] Cp. Footnote 319

[323] Cp. *Reason 4* (Chapter 7.2)

solution-finding process, especially in situations where several such requests occur at once. This would cause further disruptions and therefore diminish operational efficiency; however the safe conduct of flights could also be endangered in cases where the overall solution-finding process takes more iterations and longer time than there is holding fuel available. Therefore, dependent on binding legal provisions on how much holding fuel has to be carried aboard, there should be a time frame defined during which in-flight CDM may take place before ATC has to grant priority handling as to avoid shortage of fuel. This could be realized by specifying that when there is only holding fuel for a certain amount of time – e.g. 15 from originally 30 minutes – left, CDM may no longer be conducted. It should be ensured by adequate measures, e.g. an automatized algorithm, that this time frame is observed system-wide and constantly for all flights subject to in-flight CDM.

Chapter 7 served to analyze how OCCs will be influenced by SESAR and NextGen provisions in the future. Schemes for possible future OCC workflows and the interaction of OCCs with cockpit crews where provided for all pre- and in-flight phases which the OCCs are responsible for. The following Chapter 8 gives a conclusion of this thesis and lists thematically-related issues which should be subject of further scientific analysis.

8 CONCLUSION

This thesis reasoned the relevance of the two ATM initiatives SESAR and NextGen (Chapter 1), introduced and compared both projects' goals, ConOps and key features (Chapters 3, 4 and 5), described the functionality of today's OCCs and their integration into airline planning as well as disruption management processes (Chapter 6) and analyzed how SESAR and NextGen will possibly influence the future functioning of OCCs as well as their interaction with cockpit crews. Therefore, schemes for future OCC workflows, OCC-cockpit crew interaction and the integration of OCCs into long-term airline planning processes have been evolved in due consideration of the specifications provided in the SESAR/NextGen ConOps so far; this especially encompasses the fostered key features CDM, SWIM and TBO (Chapter 7).

In summary, it can be stated that both initiatives do not account for the integration of OCCs into the respective ATM environments sufficiently. Although being essential to the efficient conduction of ATM, there are not many specifications provided regarding the processes of OCCs as well as their interaction with other ATM stakeholders, especially ATC entities and cockpit crews. This can be realized by analyzing the evolved schemes for future OCC workflows which serve to give an initial idea of how relevant strategic and operational OCC processes will possibly be influenced by both initiatives, but which do – in accord with the results of this research and a validation report published by [JPDO /82/] in 2012 – also disclose several conceptual deficits of SESAR and NextGen when it comes to OCC integration, as closely discussed in Chapter 7:

- Insufficient focus on OCC processes and their interaction with other ATM stakeholders, especially ATC entities and cockpit crews
- Missing rules for SWIM data sharing in CDM environment (e.g. sharing of critical and/or sensitive data with third-party ATM stakeholders)
- Missing provisions for system-wide long- and short-term ATM resource allocation and bidding
- Missing rules for the prioritization of individual flights (e.g. medical emergency, fuel shortage)
- Inadequate provisions regarding the responsibility for operational NOP editing

It is without doubt that these conceptual insufficiencies must be resolved as to ensure that the overall implementation of SESAR and NextGen meets the respective ATM initiatives' objectives and time frames. This means that the OCC-related provisions given so far will have to be detailed. Otherwise, if there will not be detailed binding provisions elaborated during SESAR/NextGen development, commercial airspace users will be forced to develop their own solutions to the problems summarized above. That, however, would certainly not serve the principles of harmonization and standardization as fostered by both ATM initiatives. By recognizing this and the fact that OCCs have to be regarded as key elements in every ATM environment, it has to be said the current maladministration in both ATM modernization projects will definitely not make a contribution to the objective of increasing overall ATM efficiency and safety.

Apart from what is discussed within this thesis, there are currently many other unanswered questions which will have to be addressed by SESAR and NextGen and which may also be subject to continued research activities:

- **Interim solution for transatlantic operations during 2020 and 2025**: There will be a five-year shift between the implementation of SESAR (2020) and NextGen (2025). This implies that between 2020 and 2025, European flights will already have to be conducted according to SESAR provisions, which means applying the principles of TBO, CDM and SWIM; U.S. American flights, however, will still rely on clearance-

based operations. It is unclear how this will impact airlines which conduct transatlantic operations, as there is no interim solution for seamless operations provided yet. It has to be analyzed in how far and by which means ATM system interoperability, as fostered by both SESAR and NextGen, will be ensured during and after this period.

- **Validate SWIM reliability**: SWIM will become the technological backbone of both SESAR and NextGen as it serves as enabler for CDM and TBO and harmonizes the communication and exchange of operational data between all ATM stakeholders. Therefore, it is essential that SWIM works reliably and without major blackouts. Yet, there are currently no sophisticated concepts and/or validations available which address the topic of SWIM malfunctioning, e.g. due to server breakdown or data insufficiency, loss or manipulation.
- **Analyzing costs and benefits**: The implementation of SESAR and NextGen will be very expensive. The ATM system transformation costs are estimated to amount to a total of 1,560 Million Euro (SESAR) and 1,191 Million U.S. Dollar (NextGen) respectively.[324] This does, however, not include the individual investment costs for OCC operators, which have only been calculated based on vague assumptions. E.g., [SESAR /27/, p. 74] estimates the total investment costs for commercial airlines to be approx. 6.2 to 10.0 billion Euro, but does not specify single cost factors. As airlines have to be aware of which technologies and processes they will have to implement in order to be compliant with SESAR/NextGen provisions before they invest in cost- and time-expensive adaptions, both a validation of relevant business cases and a detailed cost-benefit-analysis should be performed.
- **Ensure interoperability with other ATM initiatives**: Until now, the focus of research activities was strongly set on the harmonization of ATM initiatives in Europe and the USA. Yet, many other countries, such as Australia, Brazil, Canada, the Russian Federation, Japan, China and India[325], are currently transforming their ATM systems in a similar way. In order to ensure global interoperability of ATM systems, it has to be analyzed in how far all these individual approaches will be compatible with each other and internationally binding ICAO provisions.

Solving these problems and intensifying the participation of affected stakeholders, especially airspace users, will increase the efficiency, safety and interoperability of global ATM systems and will help to reduce existing skepticism. This, in direct return, might cause stakeholders to invest into future ATM systems voluntarily and in time, and not only when being forced to by legal provisions.

[324] Cp. Chapter 5

[325] ICAO /85/, p. 15

BIBLIOGRAPHY

/1/ Airbus: Airbus Global Market Forecast 2012-2031 Full Book. Airbus S.A.S., Toulouse 2012. Retrieved September 22, 2013, from http://www.airbus.com/company/market/forecast/?eID=dam_frontend_push&docID=27599

/2/ Boeing: Current Market Outlook 2012-2031. The Boeing Company, Seattle 2010. Retrieved September 22, 2013, from http://www.boeing.com/assets/pdf/commercial/cmo/pdf/Boeing_Current_Market_Outlook_2012.pdf

/3/ Airbus: Airbus Global Market Forecast 2012-2031 Slides. Airbus S.A.S., Toulouse 2012. Retrieved September 22, 2013, from http://www.airbus.com/company/market/forecast/?eID=dam_frontend_push&docID=26347

/4/ United Nations: World Population Prospects - The 2010 Revision. The United Nations, New York 2013. Retrieved September 23, 2013, from http://esa.un.org/wpp/unpp/panel_population.htm

/5/ Brinkhoff, Thomas: The Principal Agglomerations of the World. Self-published, Oldenburg 2013. Retrieved September 23, 2013, from http://www.citypopulation.de/world/Agglomerations.html

/6/ United Nations: World Urbanization Prospects - The 2009 Revision Population Database. The United Nations, New York 2013. Retrieved September 23, 2013, from http://esa.un.org/wup2009/unup/index.asp?panel=1

/7/ Antweiler, Werner: Purchasing Power Parity. University of British Columbia, Vancouver 2011. Retrieved September 24, 2013, from http://fx.sauder.ubc.ca/PPP.html

/8/ European Parliament: Air Transport – Market Access and External Competence. European Parliament, Brussels 2013. Retrieved September 30, 2013 from http://www.europarl.europa.eu/ftu/pdf/en/FTU_4.6.5.pdf

/9/ Hüttig, Gerhard: Luftverkehr (Air Traffic). Lecture slides. Berlin Institute of Technology, Department Aeronautics and Astronautics, Center for Flight Guidance and Air Transport, Berlin 2013

/10/ EUROCONTROL: Annual Report 2011. EUROCONTROL – European Organisation for the Safety of Air Navigation, Brussels 2011. Retrieved September 30, 2013 from http://www.eurocontrol.int/sites/default/files/content/documents/official-documents/annual-reports/2012-annual-report.pdf

/11/ World Bank: Data – Economic Policy and External Debt. The World Bank Group, Washington (D.C.) 2013. Retrieved October 1, 2013, from http://data.worldbank.org/topic/economic-policy-and-external-debt

/12/ RITA: Flights – All Carriers – All Airlines. Research and Innovation Technology Administration, Washington (D.C.) 2013. Retrieved October 4, 2013, from http://www.transtats.bts.gov/Data_Elements.aspx?Data=2

/13/ EUROCONTROL: Summary of 2010-2030 Forecast. EUROCONTROL – European Organisation for the Safety of Air Navigation, Brussels 2013. Retrieved October 4, 2013, from http://www.eurocontrol.int/sites/default/files/content/documents/official-documents/forecasts/long-term-forecast-2010-2030.pdf

/14/ FAA: FAA Aerospace Forecast – Fiscal Years 2012-2032. Federal Aviation Administration, Washington (D.C.) 2013. Retrieved October 4, 2013, from https://www.faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/aerospace_forecasts/2012-2032/media/2012%20FAA%20Aerospace%20Forecast.pdf

/15/ ICAO: ICAO Annex 11 to the Convention on International Civil Aviation – Air Traffic Services.13th Edition. International Civil Aviation Organization, Montreal 2001. Retrieved October 4, 2013, from http://www.bazl.admin.ch/dokumentation/grundlagen/02643/index.html?lang=de&download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1acy4Zn4Z2qZpnO2Yuq2Z6gpJCDeoB9f2ym162epYbg2c_JjKbNoKSn6A--

/16/ ICAO: ICAO Doc 4444 – Procedures for Air Navigation Services – Air Traffic Management. 15th Edition. International Civil Aviation Organization, Montreal 2007. Retrieved October 4, 2013, from http://www.bazl.admin.ch/dokumentation/grundlagen/02643/02644/index.html?lang=de&download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1acy4Zn4Z2qZpnO2Yuq2Z6gpJCDe316gmym162epYbg2c_JjKbNoKSn6A--

/17/ EUROCONTROL: European Route Network Improvement Plan – Part 3: Airspace Management Handbook. EUROCONTROL – European Organisation for the Safety of Air Navigation, Brussels 2012. Retrieved October 8, 2013, from http://www.eurocontrol.int/sites/default/files/content/documents/nm/airspace/ernip-part-3-asm-handbook.pdf

/18/ EUROCONTROL: Single European Sky – For a performant [sic!] air traffic system in Europe. EUROCONTROL – European Organisation for the Safety of Air Navigation, Brussels 2010. Retrieved October 17, 2013, from http://www.eurocontrol.int/dossiers/single-european-sky

/19/ European Commission: Mobility and Transport – Air – Single European Sky. European Commission, DG Mobility and Transport, Brussels 2012. Retrieved October 17, 2013, from http://ec.europa.eu/transport/modes/air/single_european_sky/

/20/ European Union: Regulation (EC) No. 549/2004 of the European Parliament and of the Council of 10 March 2004 laying down the framework for the creation of the single European sky. European Union, Publications Office of the European Union, Resources and Logistics Directorate, Mercier (Luxembourg) 2013. Retrieved October 17, 2013, from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:096:0001:0008:EN:PDF

/21/ EUROCONTROL: Single European Sky (SES). EUROCONTROL – European Organisation for the Safety of Air Navigation, Brussels 2012. Retrieved October 17, 2013, from http://www.skybrary.aero/index.php/Single_European_Sky_(SES)

/22/ SESAR JU: 2011 SESAR Release – The first SESAR Release explained. SESAR Joint Undertaking, Brussels 2011. Retrieved October 17, 2013, from http://www.sesarju.eu/sites/default/files/documents/reports/sesar_release_Print_DEF.pdf?issuusl=ignore

/23/ Austro Control: FAB CE established. Austro Control, Vienna 2013. Retrieved October 17, 2013, from http://www.austrocontrol.at/jart/prj3/austro_control/main.jart?content-id=1311169870085&news_id=1357834797069&rel=en&reserve-mode=active

/24/ Boeing: Air Traffic Management (ATM) – The challenges of Trajectory-based Operations. A European Perspective. The Boeing Company, Seattle 2011. Restricted circulation – Boeing proprietary, for internal purposes only.

/25/ EUROCONTROL/FAA: U.S./Europe Comparison of ATM-Related Operational Performance (2010). Federal Aviation Administration, Washington (D.C.) 2012. Retrieved October 18, 2013, from http://www.faa.gov/air_traffic/publications/media/us_eu_comparison_2010.pdf

/26/ RITA: Airline On-Time Performance and Causes of Flight Delays. Research and Innovation Technology Administration, Washington (D.C.) 2013. Retrieved October 18, 2013, from http://www.rita.dot.gov/bts/help_with_data/aviation/index.html

/27/ SESAR JU: European ATM Master Plan – The Roadmap for Sustainable Air Traffic Management. 2nd Edition. SESAR Joint Undertaking, Brussels 2012. Retrieved October 19, 2013, from http://www.sesarju.eu/sites/default/files/documents/reports/European_ATM_Master_Plan.pdf

/28/ EUROCONTROL: SESAR Definition Phase – The Concept of Operations at a glance. EUROCONTROL – European Organisation for the Safety of Air Navigation, Brussels (unknown year). Retrieved October 19, 2013, from http://www.eurocontrol.int/sesar/gallery/content/public/docs/ConceptofOperations_02.pdf

/29/ SESAR JU: Members. SESAR Joint Undertaking, Brussels 2013. Retrieved October 19, 2013, from http://www.sesarju.eu/players/members

/30/ SESAR JU: SESAR Associate Partners. SESAR Joint Undertaking, Brussels 2013. Retrieved October 19, 2013, from http://www.sesarju.eu/players/associate

/31/ SESAR JU: Associate Partners to the SESAR JU. SESAR Joint Undertaking, Brussels 2013. Retrieved October 19, 2013, from http://www.sesarju.eu/players/associatesju

/32/ EUROCONTROL: SESAR. EUROCONTROL – European Organisation for the Safety of Air Navigation, Brussels 2010. Retrieved October 20, 2013, from http://www.skybrary.aero/index.php/SESAR

/33/ EUROCONTROL: ATM Master Plan. EUROCONTROL – European Organisation for the Safety of Air Navigation, Brussels 2010. Retrieved October 20, 2013, from http://www.skybrary.aero/index.php/ATM_Master_Plan

/34/ European Council: Council Decision No. 2009/320/EC of 30 March 2009 endorsing the European Air Traffic Management Master Plan of the Single European Sky ATM Research (SESAR) project. European Union, Publications Office of the European Union, Resources and Logistics Directorate, Mercier (Luxembourg) 2013. Retrieved October 20, 2013, from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:095:0041:0041:EN:PDF

/35/ EUROCONTROL: About the ATM Master Plan. EUROCONTROL – European Organisation for the Safety of Air Navigation, Brussels 2013. Retrieved October 20, 2013, from https://www.atmmasterplan.eu/about

/36/ EUROCONTROL: Funding. EUROCONTROL – European Organisation for the Safety of Air Navigation, Brussels 2013. Retrieved October 20, 2013, from http://www.sesarju.eu/about/funding

/37/ European Council: Council Resolution on "the launch of the development phase of the SESAR programme". Council of the European Union, Brussels 2008. Retrieved October 20, 2013, from http://ec.europa.eu/transport/modes/air/sesar/doc/2008_10_09_development_phase.pdf

/38/ EUROCONTROL: SESAR Key Features. EUROCONTROL – European Organisation for the Safety of Air Navigation, Brussels 2013. Retrieved October 20, 2013, from https://www.atmmasterplan.eu/views/keyfeatures

/39/ Deutsche Flugsicherung: Mediathek – SESAR (Video, 07:40 min). Deutsche Flugsicherung GmbH, Langen 2013. Retrieved October 21, 2013, from http://www.dfs.de/dfs_homepage/de/Presse/Mediathek/

/40/ SESAR JU: SESAR factsheet – Business Trajectory / '4D' Trajectory. SESAR Joint Undertaking, Brussels 2013. Retrieved October 22, 2013, from http://www.sesarju.eu/sites/default/files/documents/reports/SESAR_Factsheet_4DTrajectory__2_.pdf?issuusl=ignore

/41/ Enea, Gabriele et al.: A Comparison of 4D-Trajectory Operations envisioned for NextGen and SESAR – Some Preliminary Findings. 28th Congress of the International Council of the Aeronautical Sciences (ICAS 2012), Brisbane 2012. Retrieved October 26, 2013, from http://www.icas.org/ICAS_ARCHIVE/ICAS2012/PAPERS/310.PDF

/42/ SESAR JU: SESAR factsheet – System Wide Information Management (SWIM). SESAR Joint Undertaking, Brussels 2013. Retrieved October 28, 2013, from http://www.sesarju.eu/sites/default/files/documents/reports/factsheet-swim.pdf

/43/ SESAR JU: SESAR Concept of Operations Step 1. SESAR Joint Undertaking, Brussels 2012. Retrieved October 28, 2013, from http://www.sesarju.eu/sites/default/files/documents/highlight/SESAR_ConOps_Document_Step_1.pdf

/44/ FlitePartners: Controller Pilot Data Link Communication (CPDLC). FlitePartners Ltd., Hampshire (UK) 2011. Retrieved October 29, 2013, from http://www.flitepartners.com/Controller-Pilot-Data-Link-Communications-CPDLC.htm

/45/ European Union: Commission Regulation (EU) No. 677/2011 of 7 July 2011 laying down detailed rules for the implementation of air traffic management (ATM) network functions and amending Regulation (EU) No. 691/2010. European Union, Publications Office of the European Union, Resources and Logistics Directorate, Mercier (Luxembourg) 2013. Retrieved October 28, 2013, from http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:185:0001:0029:EN:PDF

/46/ EUROCONTROL: Regulation 677/2011 laying down detailed rules for the implementation of ATM network functions. EUROCONTROL – European Organisation for the Safety of Air Navigation, Brussels 2012. Retrieved October 28, 2013, http://www.skybrary.aero/index.php/Regulation_677/2011_laying_down_detailed_rules_for_the_implementation_of_ATM_network_functions

/47/ Dellal, Abdelkader: A Modern Approach for a Next Generation of Airlines Operations Control Centre. Master's thesis. City University of London / Jeppesen GmbH, Frankfurt/Main 2012. Restricted circulation – Jeppesen proprietary, for internal purposes only.

/48/ ICAO: ICAO Annex 6 to the Convention on International Civil Aviation – Operation of Aircraft. Part 1 – International Commercial Air Transport — Aeroplanes. 9th

Edition. International Civil Aviation Organization, Montreal 2010. Retrieved November 2, 2013, from http://www.bazl.admin.ch/experten/regulation/03080/03081/index.html?lang=de&download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1acy4Zn4Z2qZpnO2Yuq2Z6gpJCDeoB7gmym162epYbg2c_JjKbNoKSn6A—

/49/ Bazargan, Massoud: Airline Operations and Scheduling. 2nd Edition. Ashgate Publishing Company, Burlington (USA) 2010.

/50/ Barnhart, Cynthia et al.: Quantitative Problem Solving Methods in the Airline Industry – A Modeling Methodology Handbook. 1st Edition. Springer Verlag, New York 2012.

/51/ Airbus Operations: A380 Advanced Cabin Line Maintenance – Highlights of modern Airbus Line maintenance. Airbus Operations GmbH, Hamburg 2011. Retrieved November 19, 2013, from http://www.fzt.haw-hamburg.de/pers/Scholz/dglr/hh/text_2011_11_17_Cabin-Line-Maintenance.pdf

/52/ Bruce, Peter: Decision-Making and the Management of Airline Operational Disruptions. In: Aviation, Space, and Environmental Medicine, Vol. 81, No. 8 from August 2010. The Aerospace Medical Association, Alexandria (VA) 2010.

/53/ Jeppesen: Airline Operations Control (AOC) and The Integrated Operations Control Center (IOCC). Jeppesen GmbH, Frankfurt/Main 2012. Restricted circulation – Jeppesen proprietary, for internal purposes only.

/54/ Gülcan, Ibrahim (Air Berlin, OCC Management): The future OCC from Air Berlin's point of view [Interview]. Berlin 2013. Interview conducted on June 5, 2013.

/55/ Lindner, Hermann (Air Berlin, Political Affairs): The future OCC from Air Berlin's point of view [Interview]. Berlin 2013. Interview conducted on June 18, 2013.

/56/ Güldenberg, Helge (Deutsche Lufthansa, Hub Operations Center Management): The future OCC from Lufthansa's point of view [Telephone Interview]. Berlin/Munich 2013. Interview conducted on June 19, 2013.

/57/ Barraci, Nima et al.: Identification of present-day transport pilot workflow and derivation of mobile aids. Research Paper for the American Institute of Aeronautics and Astronautics. 1st Edition. Braunschweig Institute of Technology, Institute of Flight Guidance / Jeppesen GmbH, Braunschweig / Neu-Isenburg 2013. Restricted circulation – Jeppesen proprietary, for internal purposes only.

/58/ ICAO: Phase of Flight – Definitions and Usage Notes. Version 1.3. International Civil Aviation Organization, Montreal 2013. Retrieved November 19, 2013, from http://www.intlaviationstandards.org/Documents/PhaseofFlightDefinitions.pdf

/59/ Hankers, Theo: WDMD: Workflow Driven Mobile Device – Concept of information selection and display according to operational workflow relevance. 1st Edition. Braunschweig Institute of Technology, Institute of Flight Guidance / Jeppesen GmbH, Braunschweig / Neu-Isenburg 2013. Restricted circulation – Jeppesen proprietary, for internal purposes only.

/60/ Giemulla, Elmar: Luftrecht (Aviation Law). Lecture Script. Berlin Institute of Technology, Department Aeronautics and Astronautics, Center for Flight Guidance and Air Transport, Berlin 2009.

/61/ JPDO: The Joint Planning and Development Office – Making NextGen a Reality. Joint Planning and Development Office, Washington, D.C. 2013. Retrieved

November 17, 2013, from http://www.jpdo.gov/About_Us.asp

/62/ FAA: Fact Sheet – NextGen. Federal Aviation Administration, Washington (D.C.) 2007. Retrieved November 23, 2013, from http://www.faa.gov/news/fact_sheets/news_story.cfm?newsid=8145

/63/ FAA: NextGen Implementation Plan – June 2013. Federal Aviation Administration, Washington (D.C.) 2013. Retrieved November 23, 2013, from http://www.faa.gov/nextgen/implementation/media/NextGen_Implementation_Plan_2013.pdf

/64/ JPDO: Concept of Operations for the Next Generation Air Transportation System. Version 3.2. Joint Planning and Development Office, Washington, D.C. 2010. Retrieved November 23, 2013, from http://jpe.jpdo.gov/ee/docs/conops/NextGen_ConOps_v3_2.pdf

/65/ JPDO: Next Generation Air Transportation System (NGATS) Integrated Plan. Unknown Edition. Joint Planning and Development Office, Washington, D.C. 2004. Retrieved November 24, 2013, from http://www.jpdo.gov/library/ngats_v1_1204r.pdf

/66/ NCOIC: Comparison of the SESAR and NextGen Concepts of Operations. 1st Edition. Network Centric Operations Industry Consortium, unknown place 2008. Retrieved November 24, 2013, from https://www.ncoic.org/apps/group_public/download.php/12026/SESAR_NextGen_Comparison%2020090317FINAL.pdf

/67/ FAA: NextGen – Performance Snapshots. Federal Aviation Administration, Washington (D.C.) 2013. Retrieved November 24, 2013, from http://www.faa.gov/nextgen/snapshots/

/68/ ICAO: ICAO Doc 9854 – Global Air Traffic Management Operational Concept. 1st Edition. International Civil Aviation Organization, Montreal 2005. Retrieved November 25, 2013, from http://www.icao.int/Meetings/anconf12/Document%20Archive/9854_cons_en[1].pdf

/69/ ICAO: ICAO Annex 2 to the Convention on International Civil Aviation – Rules of the Air. 10th Edition. International Civil Aviation Organization, Montreal 2005. Retrieved November 27, 2013, from http://www.bazl.admin.ch/experten/regulation/03080/03081/index.html?lang=de&download=NHzLpZeg7t,lnp6I0NTU042l2Z6ln1acy4Zn4Z2qZpnO2Yuq2Z6gpJCDeoB6hGym162epYbg2c_JjKbNoKSn6A—

/70/ ICAO: NextGen/SESAR Gap Analysis – An analysis on how these programmes relate to ICAO's Global Standardisation activities. 10th Edition. International Civil Aviation Organization, Montreal 2009. Retrieved November 27, 2013, from www2.icao.int/en/TrainingRTOs/Presentations/NextGen-SESAR.ppt

/71/ ICAO: ICAO Doc 9859 – Safety Management Manual (SMM). 3rd Edition. International Civil Aviation Organization, Montreal 2013. Retrieved November 27, 2013, from http://www.icao.int/safety/SafetyManagement/Documents/Doc.9859.3rd%20Edition.alltext.en.pdf

/72/ airsight: Airport Safety Management. Training course slides. Unknown Edition. airsight GmbH, Berlin/Riga 2012. Restricted circulation – airsight proprietary.

/73/ Sudarshan, Hindupur: High Level Comparative Analysis – SESAR and NextGen initiatives. Tutorial. Unknown Edition. Seamless Sky, Montreal 2012. Retrieved November 28, 2013, from http://www.seamlesssky.com/Docs/Tutorial.D.SESAR%20vs%20NextGen.pdf

/74/ Sudarshan, Hindupur: Tutorials. Unknown Edition. Seamless Sky, Montreal 2012. Retrieved November 28, 2013, from http://www.seamlesssky.com/tutorials.html

/75/ Klooster, Joel: Controlled Time-of-Arrival Flight Trials. Eighth USA/Europe Air Traffic Management Research and Development Seminar (ATM2009), Napa (CA) 2010. Retrieved November 30, 2013, from http://www.atmseminarus.org/ seminarContent/seminar8/papers/p_064_CDA.pdf

/76/ von Castell, Martin: Analyse der Implementierungs- und Umsetzungs-empfehlungen des ICAO Advanced Surface Movement Guidance and Control System (A-SMGCS) Handbuchs. Bachelor's thesis. Berlin Institute of Technology, Department Aeronautics and Astronautics, Center for Flight Guidance and Air Transport, Berlin 2012

/77/ EUROCONTROL: Automatic Dependent Surveillance Broadcast (ADS-B). EUROCONTROL – European Organisation for the Safety of Air Navigation, Brussels 2013. Retrieved December 10, 2013, from http://www.skybrary.aero/ index.php/Automatic_Dependent_Surveillance_Broadcast_(ADS-B)

/78/ Klooster, Joel et al.: Trajectory Synchronization and Negotiation in Trajectory Based Operations. 29th Digital Avionics Systems Conference, Salt Lake City 2010.

/79/ Vivona, Robert et al.: Comparison of Aircraft Trajectory Predictor Capabilities and Their Impacts on Air Traffic Management Automation Interoperability. 11th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference, Virginia Beach 2011. Retrieved December 11, 2013, from http://www.aviationsystemsdivision.arc.nasa.gov/publications/2011/AIAA-2011-6856-TN2924.pdf

/80/ Levi, Dean (Jeppesen, Advanced Research): The OCC's role in NextGen [Telephone Interview]. Berlin/Denver 2013. Interview conducted on July 15, 2013.

/81/ SESAR JU: WP 11.1 – Flight and Wing Operations Centers (Description of Work). Version 2.0. SESAR Joint Undertaking, Brussels 2010. Retrieved November 15, 2013, from http://www.sesarju.eu/sites/default/files/documents/reports/13-10-221426-A-SJU_DoW_WP11_v2_0_FINAL.pdf?issuusl=ignore

/82/ JPDO: Flight Operations Centers: Transforming NextGen Air Traffic Management – FOC Team Study Report. Unknown Edition. Joint Planning and Development Office, Washington, D.C. 2012. Retrieved December 22, 2013, from http://www.jpdo.gov/library/07122012_AOC_FOC_complete.pdf

/83/ SWIM-SUIT: System-Wide Information Management – Supported by Innovation Technology – Project Description. Unknown Edition. SWIM-SUIT, Rome 2007. Retrieved December 22, 2013, from http://www.swim-suit.aero/swimsuit/public/SWIM-SUIT_Project_Description.pdf

/84/ Jeppesen: Report on Jeppesen goes SWIM. 1st Edition. Jeppesen GmbH, Frankfurt/Main 2012. Restricted circulation – Jeppesen proprietary, for internal purposes only.

/85/ ICAO: Integration and Harmonization of NextGen and SESAR into the Global Air Navigation System. Unknown Edition. International Civil Aviation Organization, Montreal 2009. Retrieved November 27, 2013, from http://www.afceaboston.com/ documents/events/cnsatm2009/Briefings/Thursday%20Briefs/Thursday%20Mornin g/3.%20Harmonizing%20SESAR,%20NextGen-%20Mr.%20Nagle.pdf

ANNEX 1 – AVIATION MARKET KEY INDICATORS (EUR VS. USA)[326]

		Europe		USA		Difference [absolute]
2011	**real GDP growth [%]**[327]	+ 1.8		+ 1.7		0.1
	total A/C in service [-][328]	4,440		6,650		2,210
	thereof:		Share [%]		Share [%]	
	• Single aisle	3,160	71.2	3,730	56.1	570
	• Twin aisle	680	15.3	1,030	15.5	350
	• Regional jets	410	9.2	1,770	26.6	1,360
	• Type 747 and larger	190	4.3	120	1.8	70
	real RPK growth [%]	+ 3.5		+ 2.8		0.7
	real N° of IFR flights [million][329]	9.78		9.97		0.19
2031	**est. GDP growth [CAGR]**	+ 1.9 (Airbus) + 1.9 (Boeing)		+ 2.0 (Airbus) [+ 2.6] (Boeing)[330]		0.1 [0.7]
	est. new A/C in service [-][331]	7,760		7,290		470
	thereof:		Share [%]		Share [%]	
	• Single aisle	5,800	74.7	5,040	69.1	760
	• Twin aisle	1,440	18.6	1,320	18.1	120
	• Regional jets	320	4.1	890	12.2	570
	• Type 747 and larger	200	2.6	40	0.6	160
	est. total A/C in service [-][332]	8,320		8,830		510
	thereof:		Share [%]		Share [%]	
	• Single aisle	6,120	73.5	6,090	69.0	30
	• Twin aisle	1,630	19.6	1,740	19.7	110
	• Regional jets	340	4.1	890	10.1	550
	• Type 747 and larger	230	2.8	110	1.2	120
	est. RPK growth [CAGR]	+ 4.1 (Airbus) + 4.1 (Boeing)		+ 3.3 (Airbus) + 2.8 (Boeing)		0.8 1.3
	est. RTK growth [CAGR]	+ 4.8 (Airbus) + 4.6 (Boeing)		+ 4.4 (Airbus) + 4.5 (Boeing)		0.4 0.1
	est. N° of IFR flights growth [CAGR][333]	+ 2.8		+ 2.4		0.4
	est. N° of IFR flights [million][334]	19.30		16.11		3.19

Annex 1: Aviation market key indicators (EUR vs. USA)

[326] Unless not otherwise declared, the given data refer to [Airbus /1/] and [Boeing /2/]. In the case of deviations between those both sources, both the Airbus and Boeing data are listed. A separate footnote naming either [Airbus /1/] or [Boeing /2/] as source indicates that only this source was used for the specific category. All data about Europe refer to Europe as a geographical region, not as a political union.

[327] World Bank /11/

[328] Boeing /2/

[329] EUROCONTROL /10/, p. 16 and RITA /12/

[330] No explicit explanation for this significant deviation given by [Boeing /2/]; cp. Footnote 26.

[331] Boeing /2/

[332] Boeing /2/

[333] EUROCONTROL /13/ and FAA /13/

[334] Author's own calculation

ANNEX 2 – ATM PERFORMANCE (EUR VS. USA, 2010)[335]

	Europe	USA	Difference [absolute]
Airspace size [km^2]	10.8 M	10.4 M	0.4 M
No. of ANSP [-]	37	1	36
No. of ATM control centers [-]	60	20	40
IFR flights p.a. [-]	9.5 M	15.9 M[336]	6.4
Share of IFR flights from/to main 34 airports [%]	66	63	3
Flight hours controlled (IFR) [FH]	13.8	23.4	9.6
Relative density [FH per km^2]	1.3	2.2	0.9
Average en-route related ATFM delay per IFR flight conducted [min]	1.8	0.05	1.75
Total annual en-route related ATFM delay[337] [min]	17.1 M	0.8 M	16.3
Average spatial difference between the direct flight path and the one allocated by ATC [km]	49	n/a	n/a
Overall ATM staff [-]	57,000	35,200	21,800
Thereof: Air Traffic Controllers [-]	16,900	14,600	2,300

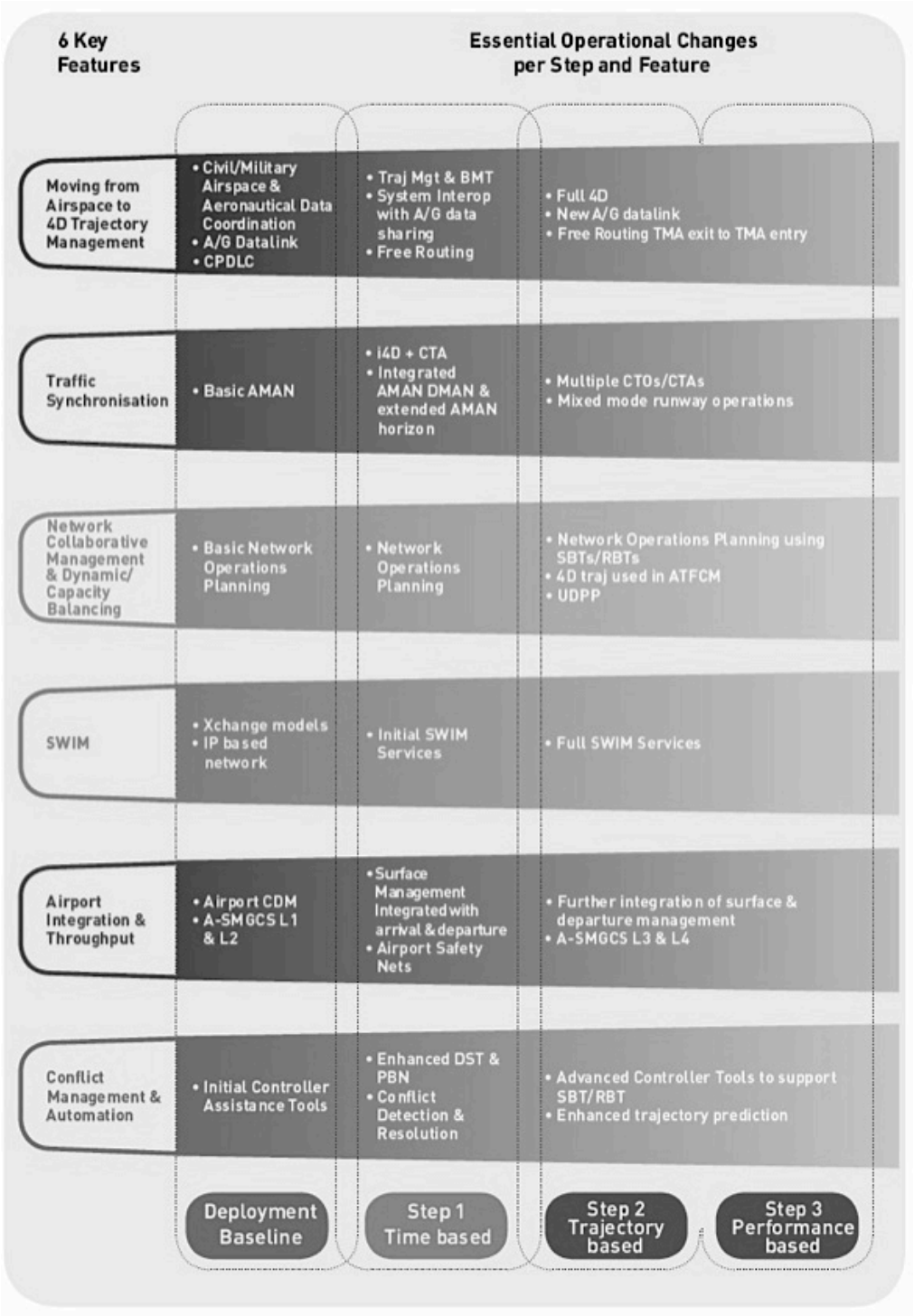
Annex 2: ATM performance key indicators (EUR vs. USA, 2010)

[335] European Commission /19/, Boeing /24/, EUROCONTROL/FAA /25/ and RITA /12/. All data about Europe refer to Europe as a geographical region, not as a political union. Thus, this table takes into account the 27 Member States of the EU, EFTA countries (Switzerland, Norway), ECAA countries (Serbia, Montenegro, Albania, Macedonia, Croatia) and countries not covered by the SES Regulations (Ukraine, Turkey, Armenia, Moldova). Iceland is not covered.

[336] This value differs significantly from the one published by [RITA /12/] for the FY 2011, which is used in Chapter 1.3 as well as in Annex 1.

[337] Only flights with a delay of more than 15 minutes are included.

ANNEX 3 – SESAR: KEY FEATURES AND DEPLOYMENT STEPS[338]



Annex 3: SESAR Deployment Phase - key features and deployment steps

[338] EUROCONTROL /38/

ANNEX 4 – TEMPLATE FOR NETWORK OPERATIONS PLAN[339]

ANNEX V

TEMPLATE FOR NETWORK OPERATIONS PLAN

The Network Operations Plan shall be based on the following general structure (that will be tailored to the various individual functions and to the time horizon of the Network Operations Plan to reflect its rolling nature and its 3 to 5 year, annual, seasonal, weekly and daily periods):

1. INTRODUCTION

1.1. Scope of the Network Operations Plan (geographical and time period)

1.2. Preparation of the plan and validation process

2. DESCRIPTION OF THE NETWORK OPERATIONS PLAN, OPERATIONAL TARGETS AND OBJECTIVES

— including the collaborative aspect of the participating operational stakeholders in terms of roles and responsibilities,

— indicating how the operational targets and objectives will be covered in the tactical, pre-tactical, short-term and medium-term phases of the Network Operations Plan and other performance targets set under the performance regulation,

— priorities set and resources needed for the planning period,

— indicating the impact on the ATM industry and other concerned areas.

3. OVERALL NETWORK OPERATIONS PLANNING PROCESS

— description of the overall network operations planning process,

— description of the strategic way the Network Operations Plan will evolve and progress to successfully respond to the operational performance requirements and other performance targets set under the performance Regulation,

— description of tools and data used.

4. OVERALL CONTEXT AND OPERATIONAL REQUIREMENTS

4.1. Summary description of the past network operational performance

4.2. Challenges and opportunities related to the time period of the plan

4.3. Network traffic forecast in accordance with Appendices 1 and 2, including:

— network forecast,

— air navigation service provider, functional airspace block and ACC forecast,

— main airports forecast,

— analysis of the traffic forecast, including a range of scenarios,

— analysis of special events impact.

4.4. Network operational performance requirements, including:

— overall network capacity requirements,

— air navigation service provider, functional airspace block and ACC capacity requirements,

— airport capacity,

— analysis of the capacity requirements,

— overall network environment/flight efficiency requirements,

— overall network safety requirements,

— contingency requirements and continuity of services affecting the network.

4.5. Operational needs as expressed by the different stakeholders, including military

5. NETWORK OPERATIONAL PERFORMANCE ENHANCEMENT PLANS AND ACTIONS AT NETWORK LEVEL

— description of the plans and actions expected to be implemented at network level, including airspace, scarce resources and ATFM,

— description of the operational performance contributions of each of the plans and actions.

6. OPERATIONAL PERFORMANCE ENHANCEMENT PLANS AND ACTIONS AT LOCAL LEVEL

— including description of each of the plans and actions expected to be implemented at local level,

— description of the operational performance contributions of each of the plans and actions,

— description of relations with third countries and work related to ICAO.

7. SPECIAL EVENTS

— overview of special events with significant ATM impact,

— individual special events and their handling from an network perspective,

— major military exercises.

8. MILITARY AIRSPACE REQUIREMENTS

8.1. Military ATM service providers responsible for areas of reserved or segregated airspace shall exchange with the Network Manager, through the relevant Airspace Management Cell, the following information according to national rules:

— airspace availability: default days/times of availability of reserved airspace,

— ad hoc requests for unplanned use of reserved airspace,

— release of reserved airspace to civil use whenever not required, giving as much notice as possible.

9. CONSOLIDATED FORECAST AND ANALYSIS OF THE OPERATIONAL PERFORMANCE OF THE NETWORK

— network, air navigation service provider, functional airspace block and ACC ATM delay/capacity targets and forecast,

— airport operational performance,

— network environment/flight efficiency performance target and forecast,

— impact of special events,

— analysis of the operational performance targets and forecast.

10. IDENTIFICATION OF OPERATIONAL BOTTLENECK AREAS AND MITIGATION SOLUTIONS AT NETWORK AND LOCAL LEVEL

— identification of operational (safety, capacity, flight efficiency) bottlenecks and potential bottlenecks, their causes and agreed solutions or mitigation actions, including options for demand capacity balancing (DCB).

Annex 4: Template for Network Operations Plan

339 European Union /45/, p. L 185/24f. (Annex V)

ANNEX 5 – EMAILS TO MR. MARC TENENBAUM (SJU)

Mr Tenenbaum is SESAR Deputy Contribution Manager and manages the EUROCONTROL research and development contribution to the SESAR Joint Undertaking (SJU).

von Castell Martin 25. Juni 2013 13:23
An: Tenenbaum Marc Details
Inquiry - SESAR WP 11.1 Gesendet - iCloud 1

Dear Mr Tenenbaum,

Being a student researcher at Berlin Institute of Technology, I am currently writing my master's thesis regarding the impact of SESAR on Airline Operations Control Centers (OCC).
Mr. Nico Zimmer from Jeppesen, Germany, forwarded your mail address to me.

As it is my objective to analyze the outcomes of SESAR on OCCs, I would like to ask if you could provide me with information concerning SESAR WP 11.1. In particular, I am interested in how SESAR will influence current OCC workflows and structures.

The WP 11.1 DoW states that a definition of future workflows and OCC structures shall be established. Unfortunately, there is not much information published on the web regarding WP 11.1 yet and the announced results by end of 2012 are not visible on the web either. Therefore, I would be pleased if you could provide me with information. Is there, maybe, something like a interim report and/or presentations for WP 11.1 available?

If you have any questions, please do not hesitate contacting me. Thank you for your cooperation!

Kind regards
Martin von Castell

Martin von Castell, B.Sc. Transportation Eng.
stud. M.Sc. Aeronautics and Astronautics

von Castell Martin 13. Juli 2013 14:47
An: Tenenbaum Marc
Fwd: Inquiry - SESAR WP 11.1 Gesendet - iCloud 2

Dear Mr Tenenbaum,

Did you receive the email I sent you on June, 25th? Unfortunately, I did not get an answer so far. I'd highly appreciate your cooperation as you would help me to analyze how SESAR interferes with airlines' Operations Control Centers.

Thank you very much!
Kind regards

Martin von Castell, B.Sc. Transportation Eng.
stud. M.Sc. Aeronautics and Astronautics

Annex 5: Emails to Mr Marc Tenenbaum (SJU)

ANNEX 6 – EMAILS TO MR. PAUL DUNKLEY (SJU)

Mr Dunkley is SESAR Joint Undertaking (SJU) Programme Manager and in leading responsibility for the entire WP 11.

von Castell Martin 25. Juni 2013 13:25
An: Dunkley Paul Details
Inquiry - SESAR WP 11.1 Gesendet - iCloud 1

Dear Mr Dunkley,

Being a student researcher at Berlin Institute of Technology, I am currently writing my master's thesis regarding the impact of SESAR on Airline Operations Control Centers (OCC).
Mr. Nico Zimmer from Jeppesen, Germany, forwarded your mail address to me.

As it is my objective to analyze the outcomes of SESAR on OCCs, I would like to ask if you could provide me with information concerning SESAR WP 11.1. In particular, I am interested in how SESAR will influence current OCC workflows and structures.

The WP 11.1 DoW states that a definition of future workflows and OCC structures shall be established. Unfortunately, there is not much information published on the web regarding WP 11.1 yet and the announced results by end of 2012 are not visible on the web either. Therefore, I would be pleased if you could provide me with information. Is there, maybe, something like a interim report and/or presentations for WP 11.1 available?

Moreover, I would like to kindly ask for the reason(s) why there are no airlines participating as members or associate partner of SESAR JU? As they are ATM participants, they will be affected by SESAR, hence I am wondering why they do not participate in creating the future ATM environment they will have to operate in.

If you have any questions, please do not hesitate contacting me. Thank you for your cooperation!

Kind regards
Martin von Castell

Martin von Castell, B.Sc. Transportation Eng.
stud. M.Sc. Aeronautics and Astronautics

von Castell Martin 13. Juli 2013 14:48
An: Dunkley Paul
Fwd: Inquiry - SESAR WP 11.1 Gesendet - iCloud 2

Dear Mr Dunkley,

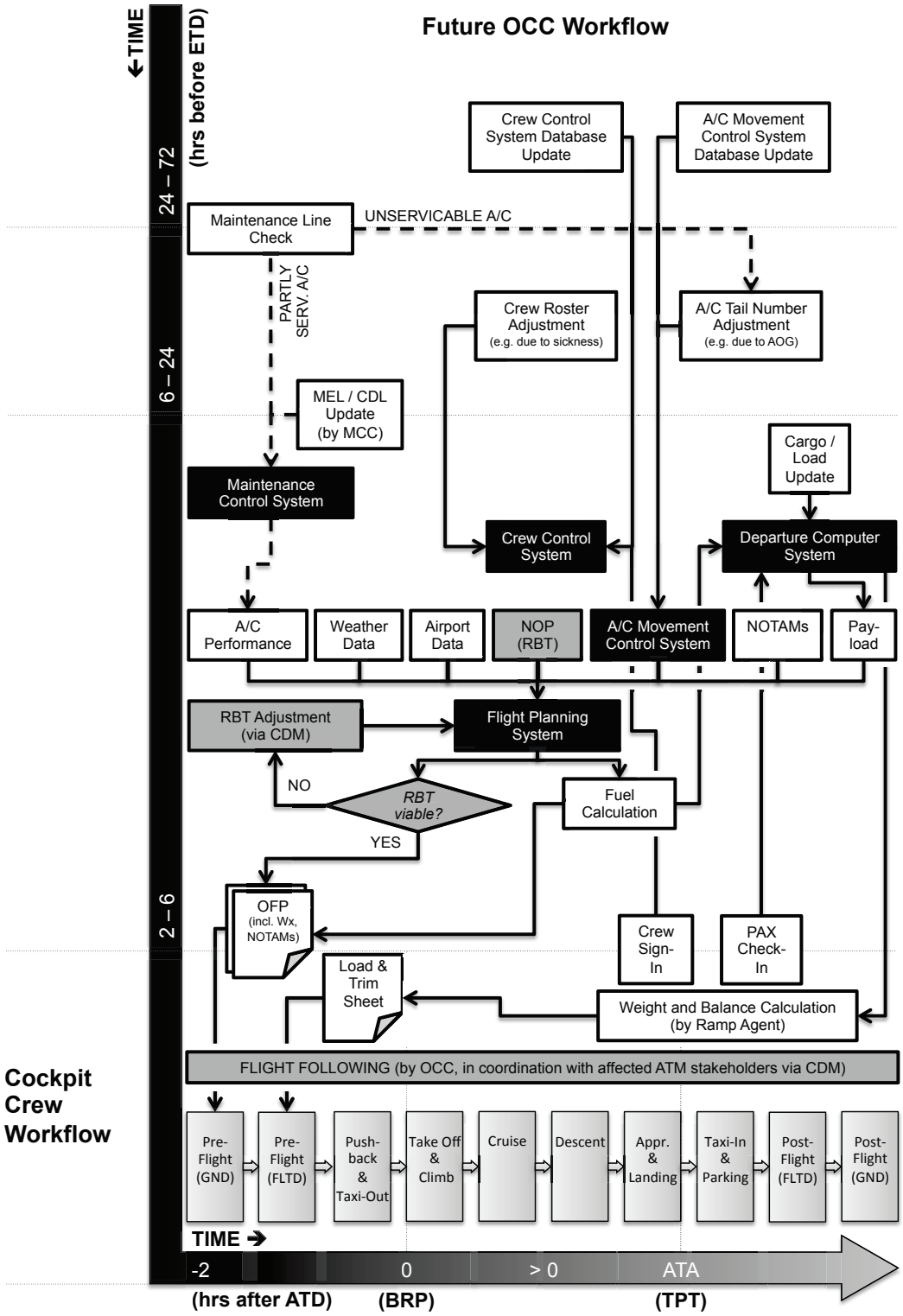
Did you receive the email I sent you on June, 25th? Unfortunately, I did not get an answer so far. I'd highly appreciate your cooperation as you would help me to analyze how SESAR interferes with airlines' Operations Control Centers.

Thank you very much!
Kind regards

Martin von Castell, B.Sc. Transportation Eng.
stud. M.Sc. Aeronautics and Astronautics

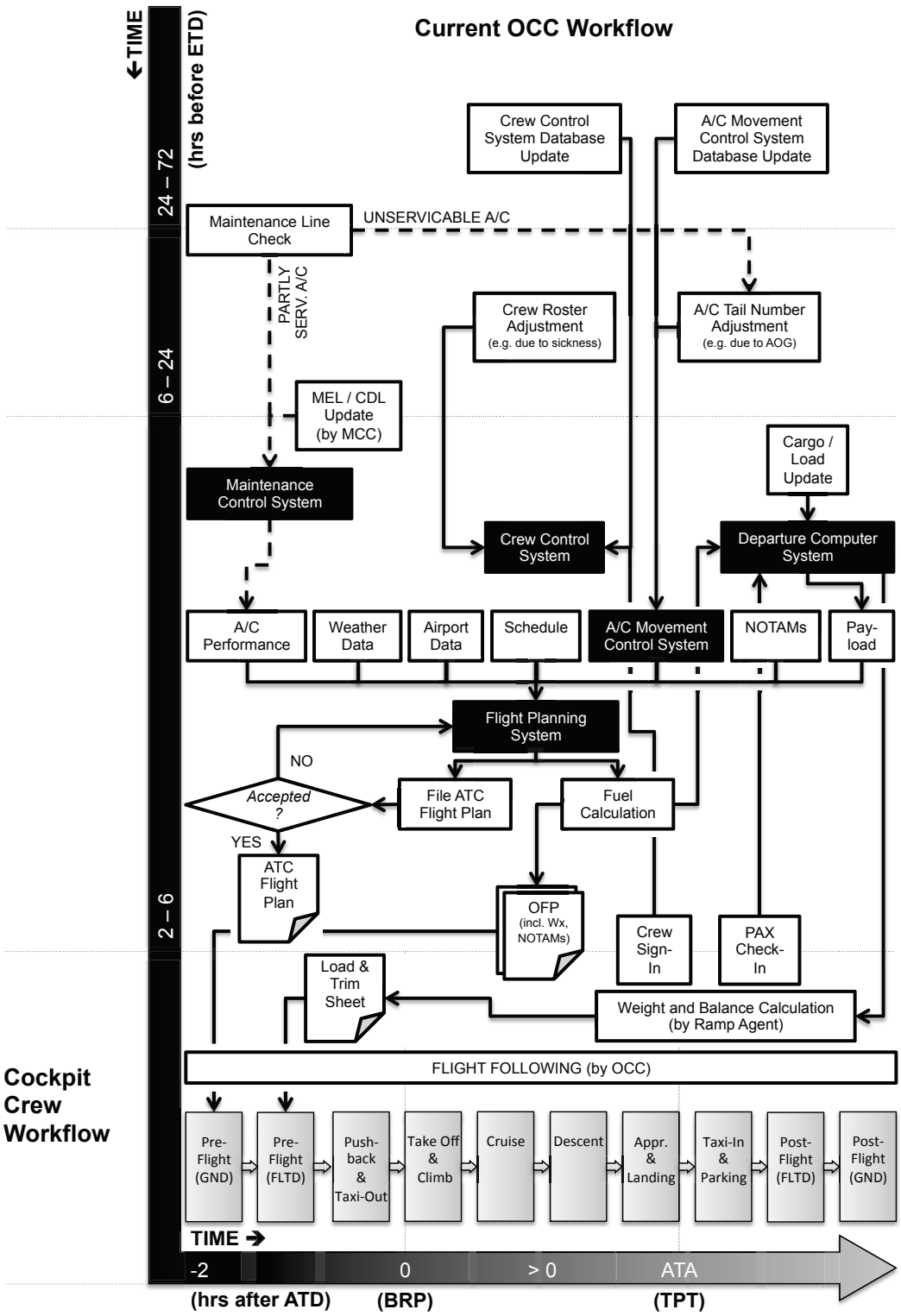
Annex 6: Emails to Mr Paul Dunkley (SJU)

ANNEX 7 – OCC-COCKPIT CREW WORKFLOW INTERACTION



Annex 7: Future OCC-cockpit crew workflow interaction[340]

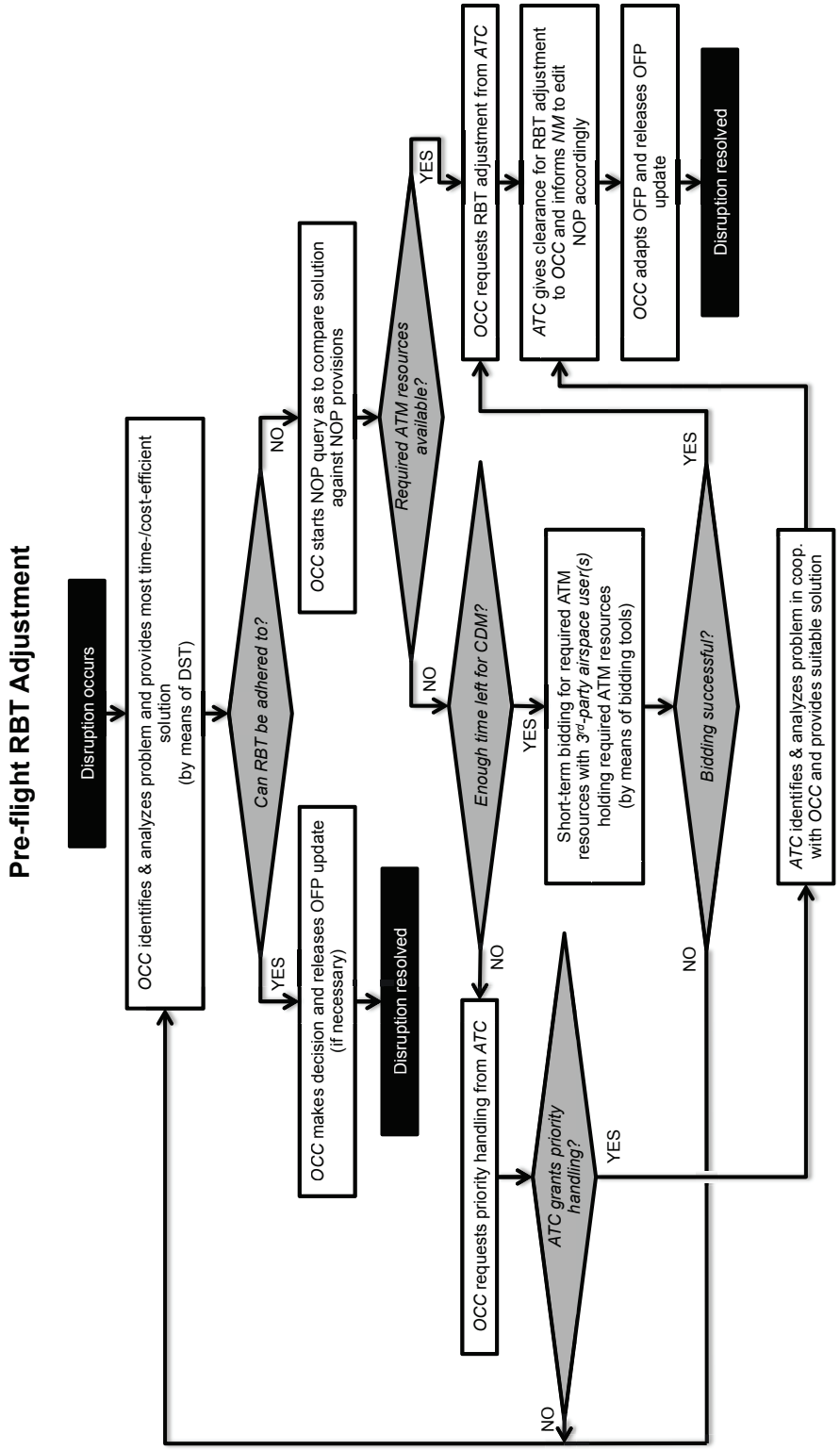
[340] Author's own illustration



Annex 7: Current OCC-cockpit crew workflow interaction[341]

[341] Author's own illustration

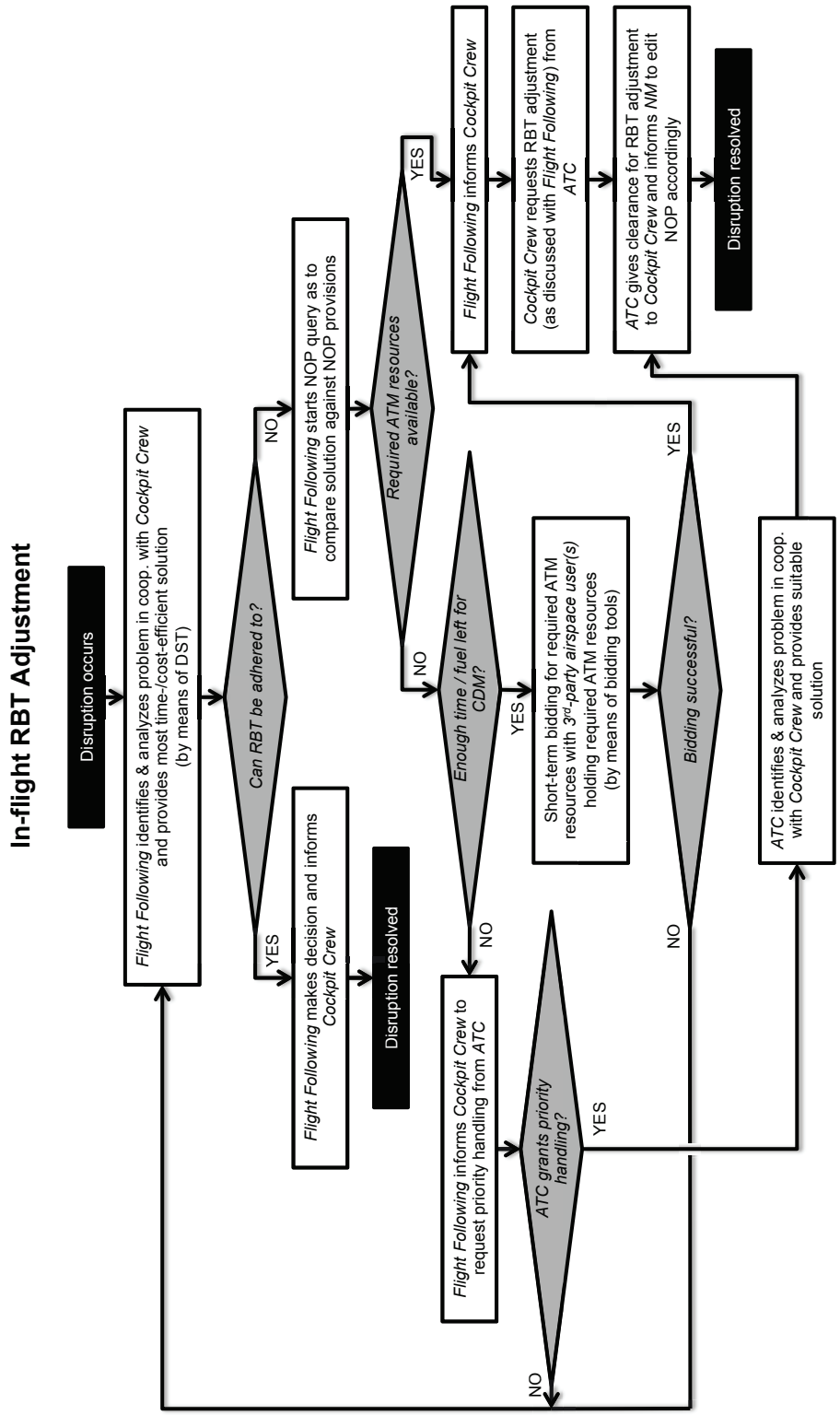
ANNEX 8 – PRE-FLIGHT RBT ADJUSTMENT BY MEANS OF CDM



Annex 8: Pre-flight RBT adjustment by means of CDM[342]

[342] Author's own illustration

ANNEX 9 – IN-FLIGHT RBT ADJUSTMENT BY MEANS OF CDM



Annex 9: In-flight RBT adjustment by means of CDM[343]

[343] Author's own illustration

ANNEX 10 – GERMAN ABSTRACT (ZUSAMMENFASSUNG)

Bemerkung: Gemäß allgemeiner Prüfungsordnung [AllgPO TU Berlin vom 13. Juni 2012, § 8 (8)] ist dieser Abschlussarbeit „als Anlage eine kurze Zusammenfassung in deutscher Sprache“ hinzuzufügen. Jene ist nachfolgend anhängig.

Einführung in die Thematik

Die Durchführung des Luftverkehrsmanagements (engl. Air Traffic Management, ATM) bedarf aufgrund der sich global ändernden Rahmenbedingungen einer radikalen Restrukturierung. Dies ist insbesondere der stetig steigenden Luftverkehrsnachfrage bei gleichbleibenden Luftraumvolumina und – damit einhergehend – dem zwingend erforderlichen Zuwachs an Flugsicherheit (engl. Safety) geschuldet. Zudem wird auch seitens der politischen Entscheidungsträger und Akteure des Verkehrssystems Luftverkehr verstärkt Wert auf die Aspekte Umweltverträglichkeit und Nachhaltigkeit gelegt.

Die Europäische Union (EU) sowie die Vereinigten Staaten von Amerika haben auf diese Situation politisch jeweils mit den ATM-Initiativen SESAR (Single European Sky ATM Research) bzw. NextGen (Next Generation Air Transportation System) reagiert. Aus den hieraus resultierenden, verbindlichen Vorgaben ergeben sich vielfältige Anforderungen an alle Teilnehmer des Systems Luftverkehr. Dies umfasst u.a. auch die Fluggesellschaften und deren operative Leitstellen (engl. Operations Control Center, OCC). Die Hauptaufgabe der im OCC tätigen Mitarbeiter besteht darin, während der letzten 72 Stunden vor Abflug und während der Durchführung eines Fluges alle für den Ablauf des Flugverkehrs relevanten Betriebsprozesse zu überwachen und zu kontrollieren sowie plötzlich auftretende, unvorhergesehene Betriebsstörungen (z.B. Luftfahrzeugdefekte, Einsetzen von Schlechtwetter, betrieblich bedingte Verspätungen) im Rahmen des *Disruption Management* zu beheben. Hierbei muss nicht nur der Flugsicherheit, sondern auch der Kosten- und Zeiteffizienz Tribut gezollt werden. Zur Erledigung ihrer Aufgaben interagieren die Mitarbeiter der OCCs mit anderen ATM-Akteuren, insbesondere mit der Flugsicherung (engl. Air Traffic Control, ATC) sowie den eigenen Luftfahrzeugführern.

Zielsetzung der vorliegenden Arbeit

Im Rahmen der vorliegenden Masterarbeit wird untersucht, inwiefern sich die o.g. ATM-Initiativen SESAR bzw. NextGen auf die Prozesse und Strukturen von OCCs sowie auf bestehende Betriebsprozesse zwischen den OCCs und den Luftfahrzeugführern auswirken werden.

Um dies zu analysieren werden sowohl die aktuellsten Projektdokumentationen beider ATM-Initiativen sowie bestehende Sekundärliteratur und wissenschaftliche Veröffentlichungen ausgewertet. Anhand der von SESAR und NextGen gemachten Vorgaben werden Schemata für die zukünftige Integration von OCCs in die lang- und kurzfristigen Planungsprozesse von Fluggesellschaften sowie für die betriebliche Interaktion zwischen OCCs und Luftfahrzeugführern abgeleitet. Basierend hierauf wird in einem weiteren Schritt analysiert, inwiefern die in SESAR and NextGen gemachten Vorgaben heutige OCC-Betriebs- und Interaktionsprozesse abbilden, berücksichtigen bzw. zu ändern versuchen. Hierbei wird insbesondere ein Augenmerk auf konzeptionelle Unzulänglichkeiten und Lücken gelegt.

Wissenschaftliches Vorgehen

Kapitel 1 beschreibt einleitend politische, ökonomische, ökologische, gesellschaftliche und operationelle Aspekte, welche die Einführung von SESAR und NextGen notwendig machen und rechtfertigen.

Nach erfolgter Einleitung dient Kapitel 2 dazu, die wissenschaftliche Vorgehensweise bei Erstellung dieser Abschlussarbeit vorzustellen und einen generellen Überblick über deren Inhalt, Rahmen und Aufbau zu gewähren.

Anschließend folgt in den Kapiteln 3 und 4 eine detaillierte Analyse der beiden ATM-Initiativen SESAR bzw. NextGen. Hierbei werden nicht nur die jeweils darin definierten operationellen Konzepte und Schüsseltechnologien, sondern ebenfalls Implementierungsaspekte berücksichtigt. Basierend auf diesen Ergebnissen werden beide ATM-Initiativen in Kapitel 5 verglichen und Gemeinsamkeiten wie auch Unterschiede, insbesondere im Bezug auf die in den jeweiligen Betriebskonzepten (engl. Concept of Operations, ConOps) vorgegebenen Schlüsseltechnologien, herausgestellt.

Nachfolgend werden in Kapitel 6 der Aufbau, die Arbeitsabläufe und die Strukturen heutiger OCCs sowie deren Integration in airline-interne Planungsprozesse dargestellt und die Arbeitsabläufe bei der Interaktion zwischen OCCs und Luftfahrzeugführern erläutert. Weiterhin werden drei unterschiedliche

Szenarien vorgestellt, welche dazu dienen, die heutige Rolle von OCCs im Bezug auf deren Umgang mit Betriebsstörungen (engl. Disruption Management) aufzuzeigen.

Basierend auf den Ergebnissen der vorhergehenden Kapitel 3 bis 6 erfolgt in Kapitel 7 eine Anwendung der aus SESAR und NextGen resultierenden Vorgaben auf heutige OCC-interne Arbeitsabläufe sowie deren gemeinsame Interaktionsprozesse mit Luftfahrzeugführern. Dieses Vorgehen dient dazu, festzustellen, wie die von SESAR und NextGen gemachten Vorgaben zukünftige OCC-Prozesse, -Strukturen und -Interaktionen beeinflussen werden. Hierzu werden – basierend auf den SESAR und NextGen ConOps – für alle Planungs- und Flugphasen entsprechende Prozess- und Interaktionsschemata visualisiert und beschrieben. Diese werden anschließend unter Einbezug der drei in Kapitel 6 definierten Szenarien hinsichtlich ihrer Verträglichkeit mit heutigen Betriebs- und Interaktionsprozessen analysiert und bewertet. Resultierend hieraus werden konzeptionelle Insuffizienzen identifiziert und analysiert, und – insoweit praktikabel – entsprechende Gegenmaßnahmen dargelegt.

Abschließend dient Kapitel 8 der Zusammenfassung der in den vorangehenden Kapiteln gewonnenen Erkenntnisse und gibt einen Überblick über thematisch-verwandte Fragestellungen, welche der näheren wissenschaftlichen Betrachtung bedürfen. Dies umfasst beispielsweise die Frage, inwiefern die Interoperabilität von SESAR und NextGen bei transatlantischen Flügen gewährleistet ist.

Resultate

Zusammenfassend lässt sich konstatieren, dass die künftige Rolle von OCCs zum jetzigen Zeitpunkt weder durch SESAR noch durch NextGen hinreichend genau definiert wird. Die Informationen, welche beide Projekte in ihren Projektdokumentationen – insbesondere den jeweiligen ConOps – in Bezug auf OCCs liefern, sind aus Sicht einer geregelten, sicheren und effizienten Implementierung sowie operationellen Anwendung als unzureichend zu bezeichnen. Aufgrund mangelhafter bzw. gänzlich fehlender konzeptioneller Vorgaben und Spezifikationen in Bezug auf die Integration von OCCs in SESAR bzw. NextGen ist es äußerst fragwürdig, ob die notwendigen Änderungen an den strategischen und operativen OCC-Prozessen kosteneffizient sowie innerhalb der vorgegebenen Projektlaufzeiten fristgerecht (SESAR: 2020, NextGen: 2025) und verlässlich funktionierend implementiert werden können.

Im Gegensatz zu ihren europäischen Kollegen von SESAR Joint Undertaking (SJU) haben die zuständigen NextGen-Projektverantwortlichen des Joint Planning and Development Office (JPDO) im Juli 2012 einen ersten Validierungsbericht[344] des NextGen ConOps in Bezug auf die Implementierung von OCCs, speziell unter dem Aspekt der beabsichtigten Ausübung der Schlüsseltechnologien *Collaborative Decision Making (CDM), System Wide Information Management (SWIM)* sowie *Trajectory-Based Operations (TBO),* vorgenommen; die JPDO empfiehlt dringend, die anhand dieses Berichts identifizierten Mängel mittels konzeptioneller Änderungen des NextGen Projektvorhabens zu beheben, da NextGen ansonsten ab initio mit operationellen Insuffizienzen – wie etwa mangelhaft definierten Regeln, sowohl für die Zuteilung von (begrenzten) ATM-Ressourcen als auch die Verwertung von vertraulichen CDM-Daten – behaftet sein wird. Zudem bemängelt die JPDO den unzureichend ausgeprägten strategischen Fokus der nach NextGen-Vorgaben zu betreibenden OCCs; dieser jedoch ist in einer CDM-Umgebung unerlässlich, da nur so die Bedürfnisse aller beteiligten Entscheidungsträger – wie durch das Prinzip des CDM beabsichtigt – bereits während der betrieblichen Langfristplanung berücksichtigt werden können.

In Bezug auf SESAR lässt sich konstatieren, dass bisher (auch auf mehrfache Anfrage bei zwei führenden SJU-Projektverantwortlichen[345]) keine konkrete Spezifizierung bezüglich des künftigen Einsatzes von OCCs im Rahmen des SESAR-ConOps vorliegt. Ebenso wenig ist eine entsprechende Validierung verfügbar. Dies erscheint insofern besonders kritisch, als dass die Implementierungsfrist von SESAR fünf Jahre vor der von NextGen, d.h. im Jahr 2020, endet. Dieses Spezifizierungsdefizit be-

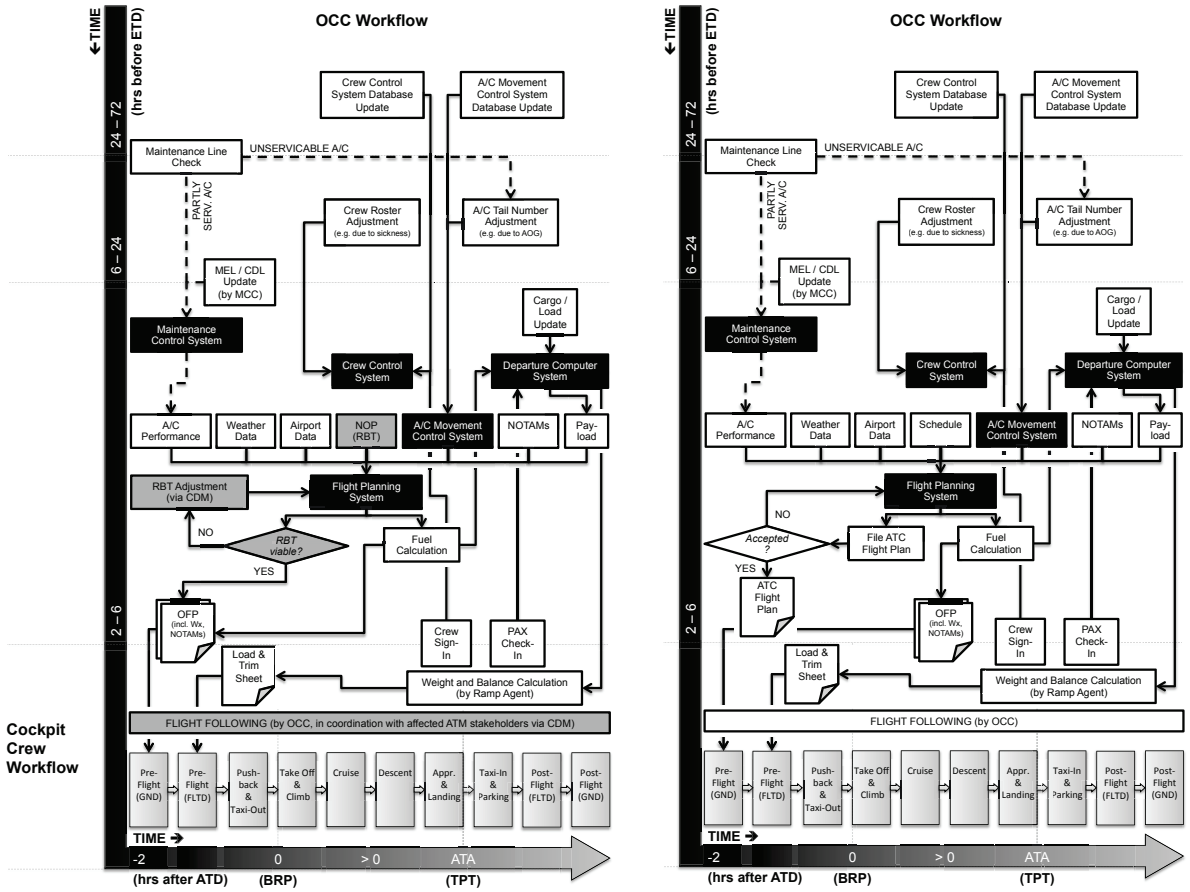
[344] JPDO /82/

[345] Herr Marc Tenenbaum, welcher als SESAR Deputy Contribution Manager für die Beteiligung von EUROCONTOL an den Forschungs- und Entwicklungsvorhaben im Rahmen des SESAR Joint Undertaking (SJU) verantwortlich ist; sowie Herr Paul Dunkley, welcher Programmmanager bei SESAR Joint Undertaking (SJU) ist und als solcher in leitender Position Verantwortung für das gesamte Arbeitspaket WP 11 – bestehend aus WP 11.1: *Flight and Wing Operation Centers* sowie WP 11.2: *Meteorological Information Services* – trägt.

klagten bei Interviews u.a. auch leitende Angestellte zweier renommierter deutschen Airlines, Air Berlin und Lufthansa.[346]

Jedoch war es möglich, anhand der von SESAR und NextGen gemachten Vorgaben zum Einsatz der o.g. Schlüsseltechnologien ein Schema zu entwickeln, welches die potentiellen Auswirkungen dieser ATM-Initiativen auf künftige OCCs und deren Zusammenarbeit mit Luftfahrzeugführern basierend auf den entsprechend heutzutage stattfindenden Prozessen visualisiert. Dieses Schema ist in der folgenden Abbildung links dargestellt; im Gegensatz hierzu ist rechts die derzeitige Situation verdeutlicht.[347] Unterschiede zwischen beiden Schemata sind grau gekennzeichnet:

Future scheme **Current scheme**



Diese beiden Schemata wurden anschließend anhand einer Gap-Analyse miteinander verglichen. Hierbei wurden folgende konzeptionelle Insuffizienzen ermittelt:

- Hinsichtlich der Anwendung von TBO besteht das Problem, dass zum Zwecke der Wahrung eines geordneten Verkehrsflusses und der Ressourcenzuteilung die verbindliche Verhandlung der beabsichtigten Trajektorien (4DTs) mehrere Wochen vor der Durchführung eines Fluges unter Beteiligung aller betroffenen ATM-Akteure stattfindet. Jedoch stehen zu diesem Zeitpunkt Informationen, welche für die operationelle Entscheidungsfindung essentiell sind, noch gar nicht zur Verfügung; dies umfasst insbesondere verlässliche Wetterprognosen sowie Informationen zum Zustand und zu eventuell vorliegenden Leistungseinschränkungen des einzusetzenden Luftfahrtgeräts. Diese und weitere Daten sind üblicherweise erst binnen der letzten 72 Stunden vor Abflug (Estimated Time of Departure, ETD) in verlässlicher Form verfügbar und werden heutzutage vom OCC verarbeitet, da diesem die operationelle Kontrolle des Flugbetriebes in jenem Zeitraum obliegt. Weil die OCC-Mitarbeiter letztendlich die verhandel-

[346] Herr Ibrahim Gülcan, Leiter des Air Berlin *Operation Control Centers* in Berlin; Herr Hermann Lindner, Direktor der Abteilung *Political Affairs* bei Air Berlin; sowie Herr Helge Güldenberg, Leiter des *Hub Operations Center* der Deutschen Lufthansa AG in München.

[347] Hochauflösende Versionen dieser beiden Abbildungen finden sich in Annex 7.

ten Trajektorien flugbetrieblich und -planerisch umsetzen müssen, erscheint es sinnvoll, den von OCCs im Vorfeld der Durchführung eines Fluges kontrollierten Zeitraum auszuweiten bzw. die OCCs in den Prozess der Trajektorienverhandlung einzubeziehen. So lassen sich frühzeitig operationelle Probleme, z.B. die Vereinbarung von Trajektorien mit Steigleistungen, welche sich mit dem einzusetzenden Luftfahrtgerät nicht realisieren lassen, erkennen und vermeiden.

- Die Erstellung und Übermittlung von ATC Flugplänen wird gemäß SESAR und NextGen künftig nicht mehr stattfinden, da anstelle dessen ein dynamischer, systemweit-verfügbarer Network Operations Plan (NOP) tritt. Dieser umfasst alle flugbetrieblich relevanten Daten zu den im Vorfeld verbindlich vereinbarten Trajektorien (Reference Business Trajectory, RBT) und dient somit als Gesamtflugplan. Im Gegensatz zu NextGen ist in SESAR definiert, dass ein Network Manager (NM) einzusetzen ist, welche(r) für die Entwicklung, Implementierung und regelmäßige Wartung des europäischen NOP zuständig ist. Beide Projekte lassen jedoch offen, welche Person oder Einrichtung für den eigentlichen Betrieb des jeweiligen NOPs zuständig ist und inwiefern diese Zuständigkeit an andere Personen oder Einrichtungen, bspw. Flugsicherungsdienstleister, übertragen werden kann.

- Die Prozesse der operativen, OCC-internen Entscheidungsfindung werden aufgrund der von SESAR und NextGen gestellten Anforderungen komplexer und den OCCs daher mehr Leistung in gleicher Zeit abverlangen. Hierdurch wird die Arbeitsbelastung der einzelnen Mitarbeiter steigen. Dies ist darauf zurückzuführen, dass der Faktor Zeit in der beabsichtigten CDM-Umgebung stringent limitierend ist. Das bedeutet, dass jedem ATM-Akteur, welcher während der Phasen der taktischen Planung und operativen Kontrolle an der Entscheidungsfindung beteiligt ist, nur eine gewisse Zeit zur Verfügung steht, um seinen Beitrag zu leisten; ansonsten kann eine rechtzeitige Entscheidungsfindung unter Berücksichtigung aller Akteure nicht gewährleistet werden. Eine Zeitüberschreitung würde Betriebsstörungen bedingen, welche zu Abweichungen vom NOP führt, weitere kurzfristige Entscheidungsprozesse notwendig macht und somit die Situation weiter verschärft, da die Anzahl und Komplexität der zu treffenden Entscheidungen exponentiell steigt. Insofern ist es wichtig, bereits im Vorfeld eindeutige Abläufe und verbindliche Regeln für das Eintreten solcher Situationen, in denen das Prinzip des CDM in der gegebenen Zeit keine vertretbaren Entscheidungen zu Tage fördert, zu treffen. Dies wird momentan weder von SESAR noch von NextGen gewährleistet.

- Sowohl SESAR als auch NextGen beabsichtigen, OCCs künftig weniger in die operativen Entscheidungsprozesse zwischen Flugsicherungsdienstleistern und Luftfahrtgesellschaften einzubeziehen und anstelle dessen verstärkt die Entscheidungsfindung zwischen ATC und Luftfahrzeugbesatzungen zu etablieren. Jedoch wird sich dies insbesondere in Situationen, in denen eine Änderung der Flugroute, Reiseflughöhe oder -geschwindigkeit beabsichtigt wird, negativ auf die Gesamteffizienz der Luftfahrtgesellschaften auswirken. Dies liegt darin begründet, dass Piloten nicht den nötigen gesamtbetrieblichen Überblick haben, um Entscheidungen, welche nicht nur die Effizienz ihres eigenen Fluges, sondern potentiell auch die von anderen von ihrer Fluggesellschaft betriebenen Flügen tangieren, selbstständig und ohne Konsultation des OCC zu treffen. Die vielen kleineren resultierenden Effizienzeinbußen werden sich zudem nicht nur auf die einzelnen Airlines, sondern in ihrer Summation auch auf das gesamte ATM-System auswirken.

Resümierend ist festzustellen, dass beide Projekte zum jetzigen Zeitpunkt die Integration von OCCs in die neu zu schaffenden ATM-Umgebungen nur unzureichend berücksichtigen und entsprechende Spezifikationen teils mangelhaft oder unvollständig sind. Unter Anbetracht der oben dargestellten konzeptionellen Insuffizienzen erscheint es fraglich, ob die Implementierung von SESAR und NextGen innerhalb der gegebenen Projektfristen (SESAR: 2020, NextGen: 2025) in Sinne der definierten Projektziele erfolgreich umgesetzt werden kann.

VERSICHERUNG

(Affidavit)

Hiermit erkläre ich, dass ich die vorliegende Arbeit selbstständig sowie ohne unerlaubte fremde Hilfe und ausschließlich unter Verwendung der aufgeführten Quellen und Hilfsmittel angefertigt habe.

Berlin, 13.02.2014

Martin Frhr. von Castell,
B.Sc. Verkehrswesen

This page is left blank intentionally.