Final Report Summary - CARGOMAP (Air Cargo Technology Road Map)

Executive Summary:

1.1. Executive summary

The Air Cargo technology Roadmap proposal focuses on the future role of air freight and the definition of a technology roadmap for future cargo aircraft responding to end user requirements and environmental needs. In order to improve seamless flow of goods, Inter-and Co-modality approaches are also considered within the SESAR operational concept.

1.1.1. Main issues of the CARGO Map project were:

• Analysis of current situation versus the demand with the involvement of the stakeholders in Europe among all actors (manufacturers, research establishment, regulators, airspace users, infrastructure providers, airport managers)

• Expected future bottlenecks/challenges in air freight transport and the identification of the corresponding requirements.

• Synopsis and evaluation of possible improvements related to future business models.

• Definition of a technology roadmap to fill the technology/regulatory/operative gaps in order to fulfil the requirements considering the current capabilities.

• Besides the core activities an effort was dedicated to disseminate the results.

From the above objectives the CargoMap project fulfilled the first two goals in the first Reporting Period and accomplished the last two in the second Reporting Period, namely the synopsis and evaluation of possible improvements related to future business models and the definition of a technology roadmap to fill the technology/regulatory/operative gaps in order to fulfil the requirements considering the current capabilities.

The present report accounts for the presentation of the outcomes of the activities of CargoMap Work Package 2. The Work Package is aimed at giving input to the definition of the Technology Roadmap accomplished within Work Package 3.

After the overview of the air cargo sector and the link to other modalities the current and future context of freight transport, their framework conditions, their strengths, opportunities, weaknesses and threats were investigated. The study on ongoing research activities was carried out to map the research activities done so far or ongoing not only directly aimed into the area of air cargo transportation, but aimed to those areas that has influence on air cargo related activities.

By building on this analysis a survey has been carried out among operators and experts in order to investigate the potential of new air cargo concepts/business models that are aimed at overcoming weaknesses and/or exploiting strengths and opportunities, relating to different timeframes and markets, in terms of geographical range and commodities. This was followed by a study to produce a number of concepts for new air cargo business models and to select the most promising in order to feed the definition of the technology roadmap in CargoMap.

All the results were collected into one single self-standing report the Roadmap document which is referring to the specific deliverables for detailed analysis. This document provides a summary of main achievements and the technology roadmap developed in the project.

The roadmap was proposed to the European Commission, industrial players, Member States and networking organizations like ACARE to select research and technology topics for future cargo aircraft RTD projects and prioritize funding.
Project Context and Objectives:

1.1.1.2. Description of project context and objectives
The call requests 3 major elements for studies: Inter-and co-modality to improve seamless flow of goods, the business case for new cargo aircraft based on a good understanding of the role of air freight and a technology roadmap for future cargo aircraft. New aircraft will need to adhere to the ATM concept of operations implemented through SESAR. The CargoMap project has addressed all these issues.

1.1.2. Current status air of freight
Air cargo is a key factor if the world economy and the airline industry. The air cargo sector has an estimated revenue of more than $ 55 billion per year. Despite the current economic downturn air cargo is expected by Boeing and Airbus to grow at nearly 6% per year globally in the next 20 years. As the air mail component will grow substantially less, this growth is mainly due to additional air freight including express traffic.

1.1.3. New challenges ahead for air cargo operations
The estimates above are based on a steady state development and assume that the additional 2.600 aircraft can be accommodated at airports and in the ATM system in 2025.
Assuming that no steady state scenario will be likely, new challenges are to be addressed in the future for the air freight system. These include:
• Airport capacity and curfews
• New commodities and new logistic concepts
• Inter modal solutions and substitution
• Environmental regulations
• ATM issues
• Oil price development

1.1.3.1. Airport capacity
Large cargo airplanes require a substantial runway length for take-off. Air cargo facilities at HUB airports have been vastly extended as these airports are located near economic centres. However already the majority of these HUB airports are reaching or have reached the maximum capacity. Further growth in passenger traffic at 5% globally will put extra demand on these HUB airports.
As a consequence one should expect that dedicated air cargo traffic will be diverted from HUB airports to regional airports to alleviate the congestion at HUB airports in Europe. At these regional airports additional runway length may be needed. But more traffic will create additional complaints about noise and emissions leading to curfews and restrictions. There may also be more truck flights in those regions that will create additional congestion on regional roads.

1.1.3.2. New commodities and new logistic concepts
New logistics concepts are being developed whereby machinery and customer goods are divided into standard modules and customer specific elements. These customer specific elements are often electronics related. To minimize warehousing of these expensive customer related items, on demand services are required. Air cargo will be called in to deliver the customer specific parts whilst the rest of the standard parts will be shipped by sea. This new trend may create an additional demand in air cargo, not yet fully recognised in the aviation industry estimates from a few years ago.

1.1.3.3. Intermodal solutions and substitution
Can air cargo create a solution to alleviate the road congestion that will result from economic growth at Europe's harbours? Again in the Out of the Box thinking one could imagine dedicated regional transport aircraft that would serve the European economy (the European banana) and perfectly fit into a multi modal transport chain, replacing the traditional European
surface transport modes and reducing congestion on Europe's already crowded roads.

1.1.3.4. Environmental regulations
New environmental regulation may be introduced in Europe like the ETS system. This may ultimately also effect air freight operations. New restrictions may be placed on airport use especially at night, in view of noise regulations. This means that old converted aircraft may no longer meet the environmental regulations or be no longer economic to operate. The future cargo aircraft will have to meet more stringent environmental criteria and a new generation of long range and short range cargo aircraft will be needed. There may be a need to develop new cargo aircraft that can comply with new regulations.

1.1.3.5. ATM issues
The SES initiative in Europe will change Air Traffic Management in Europe. According to the SESAR operational concept, air traffic will be depending on integrated route planning. Future air cargo operations will have to comply with this planning. As long as there is no fully integrated civil/military use of airspace, it is likely that airways will still be used to which air traffic has to adhere. These airways become already crowded for en-route traffic in Europe. An assessment needs to be made what effects can be expected from increased cargo traffic.

In the Commission sponsored EPATS project that estimated the demand for air taxi operations in Europe, assessments were made about the altitudes and frequencies that air taxi aircraft would use to serve Europe. These estimates showed that due to the modest distances that air taxi aircraft would need to travel, limited interference with large passenger airline operations is to be expected, as the air taxi aircraft will generally fly below 19,000 feet. A similar picture may be expected for novel regional air cargo aircraft. But the CARGOMAP study needs to assess the issue.

1.1.3.6. Oil price development
The development of oil prices is likely to go into an upward trend. Oil reserves may become scarce, whilst the demand for oil products (China development, plastics industry etc) may still rise. That means that fuel for air transport may become more expensive and new energy sources can be used. In the short run that may be synthetic and bio based fuels (Algae) and in the longer runs hydrogen or nuclear based energy sources. Converted old aircraft may then no longer be cost effective to operate. CARGOMAP has developed a technology roadmap for future air cargo aircraft. The assessment created sufficient information to formulate future actions for research by the Commission.

1.1.4. Project concept
In order to deal with the issues requested by the call, the project took the following logical steps:
- Analysis of current situation and expected future bottlenecks/challenges in air freight transport
- Synopsis and evaluation of possible improvements (related to future business models)
- Technology roadmap

1.1.5. Problems addressed by the project
Based on the business case for future air cargo operations, the project developed a technology road map to be used by the European commission in order to define the content of future calls for proposals of the air transport and aeronautics work program in the Framework programs.

1.1.6. Relevance to the topic addressed by the call
The project is highly relevant as in previous years the issue of future air cargo aircraft technologies has not been addressed neither in ACARE nor in the framework program. As new opportunities may exist that may create the need for novel dedicated air cargo aircraft that could be developed by the European industry, the project is highly relevant in determining future actions by the European Commission.

1.1.7. Relevant scientific, technical and socio-economic objectives
Air cargo is an important element of the current and future economy. Without adequate air cargo the economy will be severely
damaged. The project investigated the needs for future air cargo operations and aircraft and also investigated the need and possibilities to substitute other modes of cargo transportation by air cargo. The project investigated if novel aircraft will be needed to satisfy the demand for air cargo and the technologies needed. From that a research roadmap was derived.

1.1.8. Contribution of CargoMap to the European air transport research in comparison to other projects
In Europe the focus on cargo has been on trucking and rail transport as well as inland shipping. Up to now little research was devoted to air cargo mainly because the market could be served by converted aircraft or derivatives of existing aircraft. No dedicated research projects were supported by the European air transport research.

1.1.9. Links of CargoMap with other projects
Cargo map identified novel technologies needed for air cargo operations and aircraft. Most of these technologies derived from research already done on behalf of passenger aircraft development and cargo operations in general. The project identified these in order to avoid duplication of efforts. The project focused on those technologies that are unique to air cargo operations and aircraft of the future. Within the European framework program these issues have not yet been addressed.

1.1.10. Progress beyond the state-of-the-art
The project investigated what new challenges and opportunities exist for new air cargo operations in the future, responding to societal challenges and the concept of seamless multi modal transport chains. Whilst novel technologies were identified, only those specific to air cargo operations are shown in the roadmap, assuming that generic technologies in aviation will take place. The roadmap identifies current and planned research and missing elements to enable a new generation of air cargo aircraft to be realised.

Project Results:
1.2. Description of the main S&T results/foregrounds
1.2.1.1. Innovative air vehicles to serve the future air cargo market
CargoMap proposed and analysed a number of alternative solutions that may serve future demands in air cargo. These solutions relate to types of aircraft, operational concepts and new business models. CargoMap has identified 18 different types of aircraft configurations that could serve the air cargo market starting from 2030.

The proposed solutions were compared with respect to three major key performance indicators:
• Speed
• Cost
• Frequency

TYPE SPEED FOCUS COST FOCUS FREQ. FOCUS REMARKS
Long haul
Very large WIGE aircraft, payload 680 tons
Could also be an amphibious aircraft
Very large subsonic aircraft, payload 300 tons
Also for outsize cargo requirements
Novel subsonic aircraft based on BWB technology, payload 100 tons
Same speed as today but at reduced cost.
Use of standard containers.
Should be developed into a family concept.
Slow flying aircraft with payload of 100 tons
Will be very environmentally friendly
Supersonic cargo aircraft
Speed range could go from M1,3 up to M 2,5
Hypersonic air cargo aircraft

Could fly between Mach 5 and 8
Morphing subsonic aircraft able to perform formation flights
Aircraft would be able to fly in close formation of a few wingspans
Small aircraft that could be joined in flight to gain fuel efficiency and allow small cargo volumes to be delivered
Aircraft would depart at different locations, join up in the air to create an efficient large flying body and leave the formation near to the destination
Small aircraft with intercontinental range
Aircraft would fly dedicated to high value cargo
Medium / short haul
New large medium haul aircraft with > 100 tons capacity

Large Airship
Type of HULA airship
New regional air cargo aircraft with a capacity of 50 tons

Tilt rotor aircraft with a capacity of 20 tons
The speed would be improved due to an almost door to door delivery
Advanced rotorcraft with payload of 10-20 tons

Make use of advanced VTOL/STOL concepts
The speed would be improved due to an almost door to door delivery
Advanced small aircraft

Could make use of fanwing concept
Advanced small aircraft

10 tons payload
Replacement of Cessna caravan type of aircraft
4 tons payload
Urban flying vehicles
UAS systems

1.2.1.2. The research roadmap
The CargoMap research roadmap identifies research topics that need attention in the future referring to the SRIA adopted time frames 2020, 2035, and 2050. Results should be available within those time periods. Results should be mature, integrated and validated. In most cases technology demonstration is needed.
The roadmap is organised in tables. A distinction between operations research and technology research is made. The Table indicate where research is already performed or planned to enable the reader to understand where specific research, technology and demonstration efforts are needed.

Topic 2020 2035 2050
Market
Changes in market demand for air cargo Develop simulation models to understand the future direction of air cargo demand
Update models Update models
Understand customer satisfaction criteria including the elasticities for time, cost, frequency, environment and safety/security

Develop econometric models to estimate customer demand Update models Update models

Planning of intermodal transport chains Strengthen the discussion on a European scale to agree on intermodal steps in the future. Enable the transition from the current independent supply networks to open global networks. Continue the forum Seamless intermodal transport a fact

Create a model for fair comparison of different offers by different modes to forwarders Modelling of price alternatives and conditions; standard lay out of websites Unified European system available to all forwarders

Improve a system of data exchange between the different transport modes Uniform format developed; oversight planned

Oversight implemented

Agree on a universal system for E freight Develop uniform standard for E freight. Agree on ITC networks that will be used by all organisations in the transport chain E freight implemented

Universal system for single ticketing, tracking and indicating alternative transport opportunities in case of disruptions

Introduce a customer oriented transport chain, providing real time information, single point of contact, single ticketing and uniform tracking numbers. Shippers will have access to alternative transport opportunities during the planning and during the transport itself. This information will be provided on alternative transport cost, frequency, time to delivery and CO2 emissions.

Uniform Customer oriented decision tool is implemented

Topic 2020 2035 2050

Airports/ landing spots
Investigate opportunities to use regional airports and landing spots for air cargo delivery Make a European inventory+ Do not close regional airports too soon Open up regional airports to air cargo

Identify possibilities for VTOL/ STOL locations in Europe Make an inventory of possible locations Designate landing spots

Usage of military airports Make an inventory of military airports and barriers for air cargo services Select military airports to be used by air cargo

Design systems for short stay at warehouses IT systems to speed up warehouse placement Air cargo will stay in a warehouse no longer than one day

Design IT systems for quick customs clearance Airport clearance should be accomplished within one day

Airport services to be open 24/7 if demanded by operators Ensure 24/7 access through advanced security systems

Aircraft need to be designed so that loading and off-loading is independent of airport facilities Design for compatibility with envisaged airports Develop new devices that make loading possible using robots All robot handling

Airports at sea or shores Design of cost effective solutions Implement

Time efficiency
Automated ATM Implement SESAR Design for totally automated ATM based on CNS Totally automated ATM implemented

Develop automated separation devices and on board seek and avoid equipment Preliminary design studies Prototype testing Implementation

Airports can be used without ground NAV equipment Test WAAS, LAAS Implement airborne RNAV Fully independent systems implemented

Air cargo operators are linked to SWIM and CDM Test CDM and SWIM Implement Swim and CDM

Automated self-separation on the ground and avoidance of runway incursions Develop self-separation tools Test and implement equipment

Implement point to point flying Implement FUA and FABs Implement one single European sky; use of military airspace will be possible on real time basis

Industry action

Develop an industrial master plan to develop and manufacture novel aircraft Set up a European interest group to develop new cargo aircraft (Subgroup in ACARE?) European group has produced the first aircraft Range of aircraft developed in Europe
Make a joint market analysis of the world market for novel aircraft. Start making a market analysis and business plans. Market analysis updated.

Look for synergies with passenger / military aircraft developments. Create a forum for exchange.

Enablers

Identify RTD capabilities in Europe and identify blind spots. RTD capabilities are upgraded to respond to the needs of the air cargo market. RTD knowledge, capabilities and facilities in place to respond to the needs of the air cargo market. Upgrades realized.

Sufficient staffing is available. Education will respond to the needs of the air cargo market. Training is in line with most recent developments. Based on the market analysis make a staffing plan. Education and training fully in line with market needs. RTD funding available to enable actions and research to be performed. Specific EU funding is available. National and industrial funding is coordinated. Development of a separate SRIA for air cargo. Separate SRIA for air cargo available. Funding at EU, MS and industry level aimed at developing the next generation of air cargo planes. Continued funding.

Initiate another air cargo out of the box project to seek innovative ideas. EC funding available for out of the box workshop, assessment and Level 0 projects for incubation. Continued funding. Seek alignment with EDA. Fully integrated approach.

Security

Advanced screening devices to be developed. Low cost, flexible and universal screening devices to be developed. Advanced screening devices applied. Advanced screening devices constantly upgraded.

Cyber war hardened IT systems, avionics and ATM. Develop anti cyber-crime methods. Continue. Continue.

Full protection against manpads for air cargo aircraft. Design low cost devices against manpads. Design low cost systems against new external hazards. Continue.

Safety

Certification keeps up with technological developments and is not a barrier to innovation. A fresh look at risk based certification is started. New certification methods are implemented.

Certification cost and time is reduced by 50%. New certification methods are aimed at reducing cost and time. 50% reduction of certification time and cost is achieved. Certification is based on simulation.

Aircraft are simple to fly. Use of social media in aviation is fully implemented. Design for simplicity.

Auto recovery systems prevent crashes. Design full proof auto recovery systems. Auto recovery systems are standard.

Aircraft data telemetry is implemented. Design effective data telemetry and avoid black boxes. Implemented.

Aircraft crashworthiness is improved. Develop methods to improve survivability. Aircraft crashes are 99% survivable.

1. Table: Operations research topics and actions

1.3. Aircraft related research topics

Topic 2020 2035 2050

Configurations

Configuration studies long and medium haul aircraft. Configuration studies are performed to select the best possible future configurations based on the expected market demand.

New large aircraft are expected to enter into the market in 2035. Configuration studies completed, especially on BWB aircraft. Advanced configuration studies.

Technology development and demonstration for successor Cessna caravan type of aircraft. As the replacement of these small aircraft is imminent, configuration studies should lead to technology demonstration, a final design and manufacturing. Studies should lead to a joint European industry action.

Configuration studies for VTOL/STOL aircraft. VTOL/STOL solutions have not been studied for some time except for helicopters and tiltwing. New configurations need to be developed and demonstrated. Configuration studies completed as is design. Start production.
VTOL/STOL technology Novel designs are needed for VTOL/STOL aircraft that are efficient and low noise. The EC promotes innovative ideas by challenging the aviation community in the same way as DARPA operates. Designs lead into production of efficient and environmentally friendly VTOL/STOL.

Studies on small UAS Small UAS can be developed that can be used in an urban environment. Safety standards, technology and guidance and control devices need to be developed. Manufacturing of small UAS started.

Unpiloted technology Research is aimed at developing pilotless aircraft and their operations in 2035, with appropriate standards and complying with the civil aviation safety standards of 10-9. Flying urban UAS can be demonstrated.

New aerodynamic shapes Research should be focused on new aerodynamic shapes rather than the traditional ones. BWB, boxed wing etc. should be developed and tested to understand the potential. New aircraft to be designed with new shapes.

Research on the fanwing concept Research should demonstrate that the fanwing concept is a promising technology. Decide whether the fan wing concept is credible.

Propulsion
New ultra efficient engines to be developed. These could be hybrid engines powered by LNG or Hydrogen. Research into novel engine configurations. Research and demonstration of novel engine configurations.

Successor engine of the PT6 family designed in Europe. Research, demonstration and development.

Electrical engines to be designed and the associated battery technology further developed. Research into light weight engines and batteries. Demonstration efforts.

Conformal solar panels to be developed. RTD into the feasibility of sheets of flexible highly efficient solar cells. Implementation.

APU replacement by electrical systems or fuel cells. RTD into the safe and efficient fuel cells. Implementation.

Advanced turbo prop/diesel engines with less fuel burn, noise and emissions. RTD into novel engines, demonstration activities.

Advanced propeller and rotor design with low noise characteristics and high efficiency. RTD and demonstration of new prop configurations.

Advanced VSTOL/autogyro engines. RTD on novel efficient engines. Demonstration and final design.

Equipment
Autonomous flight equipment. RTD on the concept of autonomous flight. Implementation possibly first with safety pilot on board.

Advanced avionics, low cost, low weight, low power uptake, small volume. RTD in new avionics integrating social media.

Low cost fly by wire. RTD to develop advanced fly by wire systems.

Novel air cargo containers that will fit into standard 20/40 feet containers. Containers are developed in such a way that the contents can be conditions (temperature, humidity, pressure etc.) RTD for the design of novel air cargo containers.

Aerodynamics
Advanced aerodynamic solutions including laminar flow, drag reduction, BLI, advanced VTOL/STOL design. Fresh look at aerodynamics tailored for air cargo aircraft configurations. Validation, demonstration and design.

Morphing technologies for formation flight RTD for morphing wings. Application.

RTD for coupled flight. RTD to establish the feasibility of coupled flight. Integration and demonstration.

Advanced rotorcraft configurations. RTD into novel concepts including stopped rotor, X wing, tilting wings etc. Integration and demonstration.

Structures
Advanced materials and structures designed for low weight and low cost. RTD for novel ways to construct airplanes with light structures without pressure hull. Integration, demonstration and design.

Advanced nano technology. RTD for advanced nano materials for aviation. Demonstration and design.
Totally recyclable aircraft RTD for reuse and recycling of aircraft and airport parts Demonstration Aircraft can be 100% recycled
Crashworthy structures RTD for more crashworthy structures including ditching Demonstration and implementation
Low cost production methods RTD for low construction cost, especially for small production runs Demonstration and implementation
Unscheduled maintenance avoidance RTD for low cost maintenance by lengthening maintenance periods, avoidance of unscheduled maintenance Demonstration and implementation

Table 2: Aircraft related research topics

Potential Impact:
CargoMap made recommendations to the need for the European Commission of allocating research funding to the air cargo market aircraft technologies.
In order to prepare the roadmap, different novel aircraft were assessed and the timing of these aircraft. From that main characteristics derived and the timeframe in which these should be available. Enabling technologies were identified. The team analyzed the availability of these enabling technologies in time, based on current European and national research. The roadmap show which specific enabling technologies will be needed and at what time. Suggestions were created for the Commission.
Novel concepts in aviation need a long time to mature. So it is appropriate to publish a technology roadmap in 2012 aimed at developing future technologies specifically related to novel air cargo aircraft. In this technology roadmap the focus is on technologies specifically aimed at air cargo operations and the dedicated air cargo aircraft. Reference is made to generic technologies in aviation but the roadmap specifically address the air cargo related issues.
Integration in the next ATM system implemented by SESAR are be assessed. This includes the possible use of single pilot operations and pilotless aircraft operations and the impact on ATM.
CargoMap provides an overview of estimates by the aircraft industry in Europe and the US on the number of aircraft needed in 2025 and the segmentation between belly freight and dedicated freighter aircraft. It assesses if aircraft conversions as predicted by the aircraft industry will serve the novel demands in air cargo.
CargoMap also examines novel trends in air freight that may be the result of economic growth in Asia and the connections between Europe and Asia. CargoMap also analyzes the potential use of extended air cargo operations in Europe and its consequences. Time focus is medium and long-term.

List of Websites:
- The address of the project’s website: http://www.cargomap.eu/
- Project Coordinator: Slot Consulting - SLOT
- Web: www.slot-consulting.eu
- Person in charge: Mr Roland Guraly
- E-mail: cargomap@slot-consulting.eu
- Phone: +36-1/2903498
- Fax: +36-1/2921052

Related information

Result In Brief
Enabling next-generation cargo aeroplanes

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