



## **Building an air cargo network planner - utilizing TM1 and CPLEX**

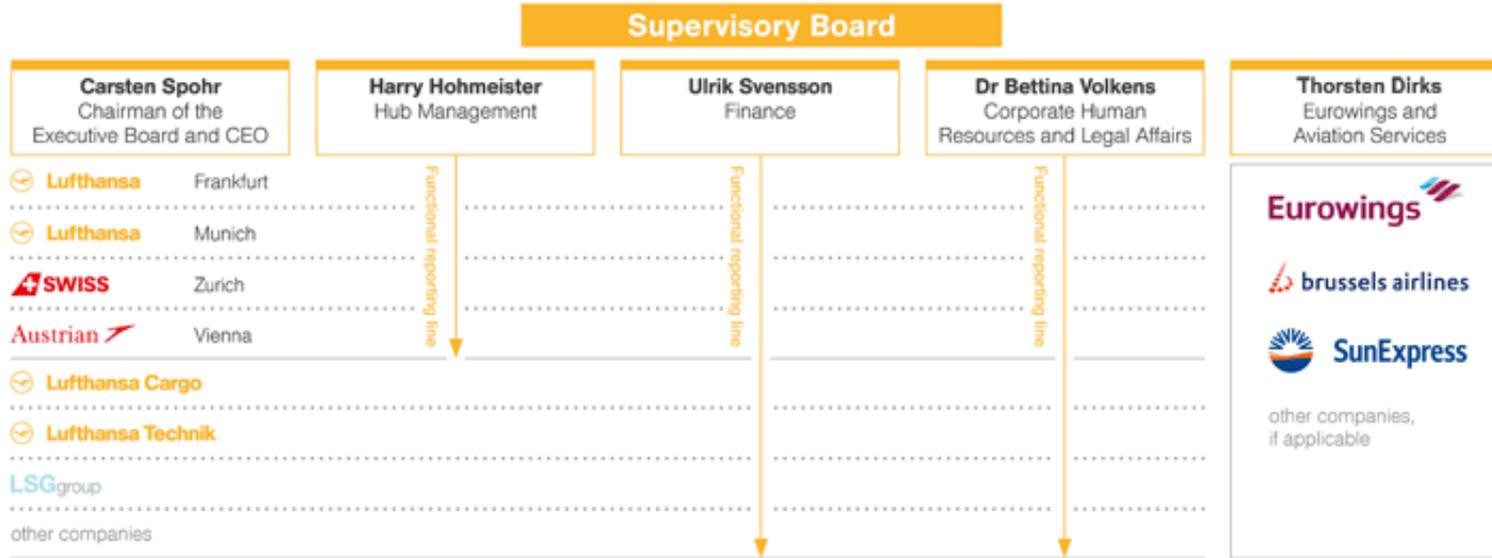
19.06.2018, Antonino Franco  
Senior Manager Market & Network Planning



**Lufthansa Cargo**



# Lufthansa Group structure



## Lufthansa Group 2017

**Revenue** in EUR bn  
**Adj. EBIT** in EUR  
**Employees** number

**35.6**  
**2,973**  
**128,856**

## Lufthansa Cargo

**2.5**  
**242**  
**4,511**

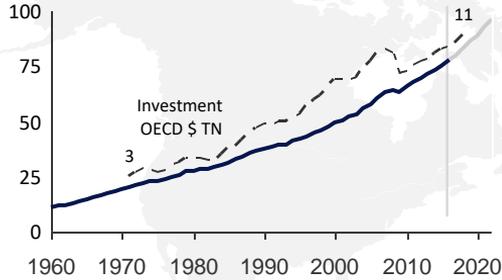
# Air Freight - demand stays on its long-term growth path

## eCommerce is booming worldwide



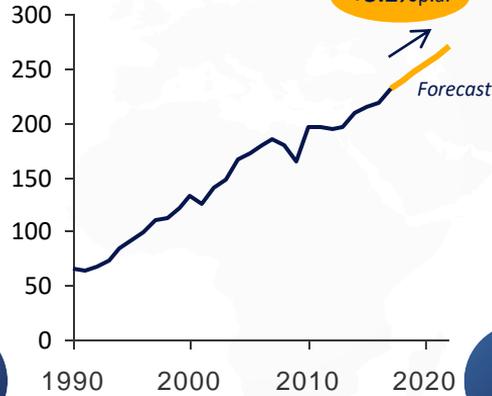
### Global Economic Growth

World GDP US\$ TN at constant 2010 prices



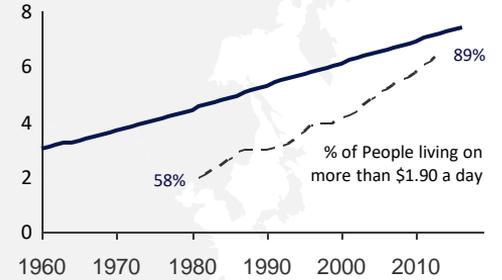
### Air Freight

IATA Global freight and mail, Mrd. TKT



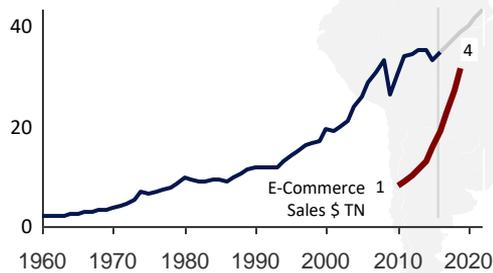
### World Population and Economic Wealth

World Population Billion People



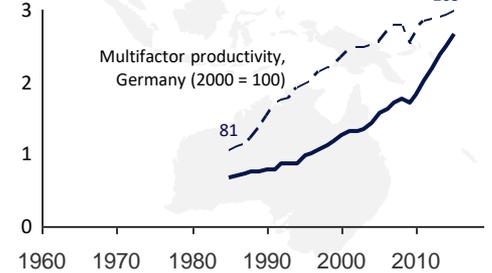
### Worldwide Trade

Merchandise Trade US\$ TN at const. 2010 prices



### Technological Progress

Patent Applications Million



# Lufthansa Cargo – we offer our product range worldwide across our own as well as our partner platforms



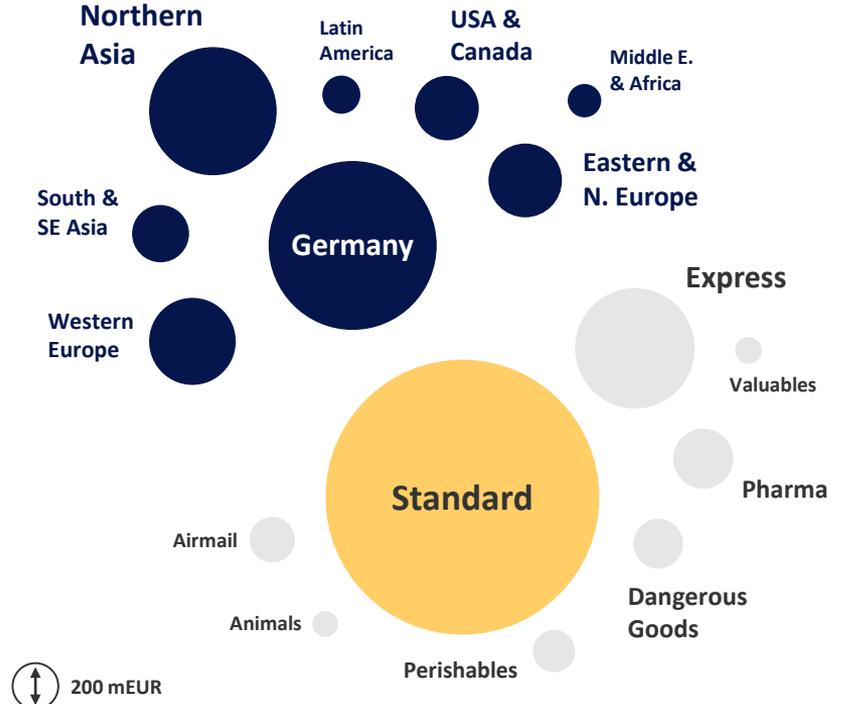
## Our network



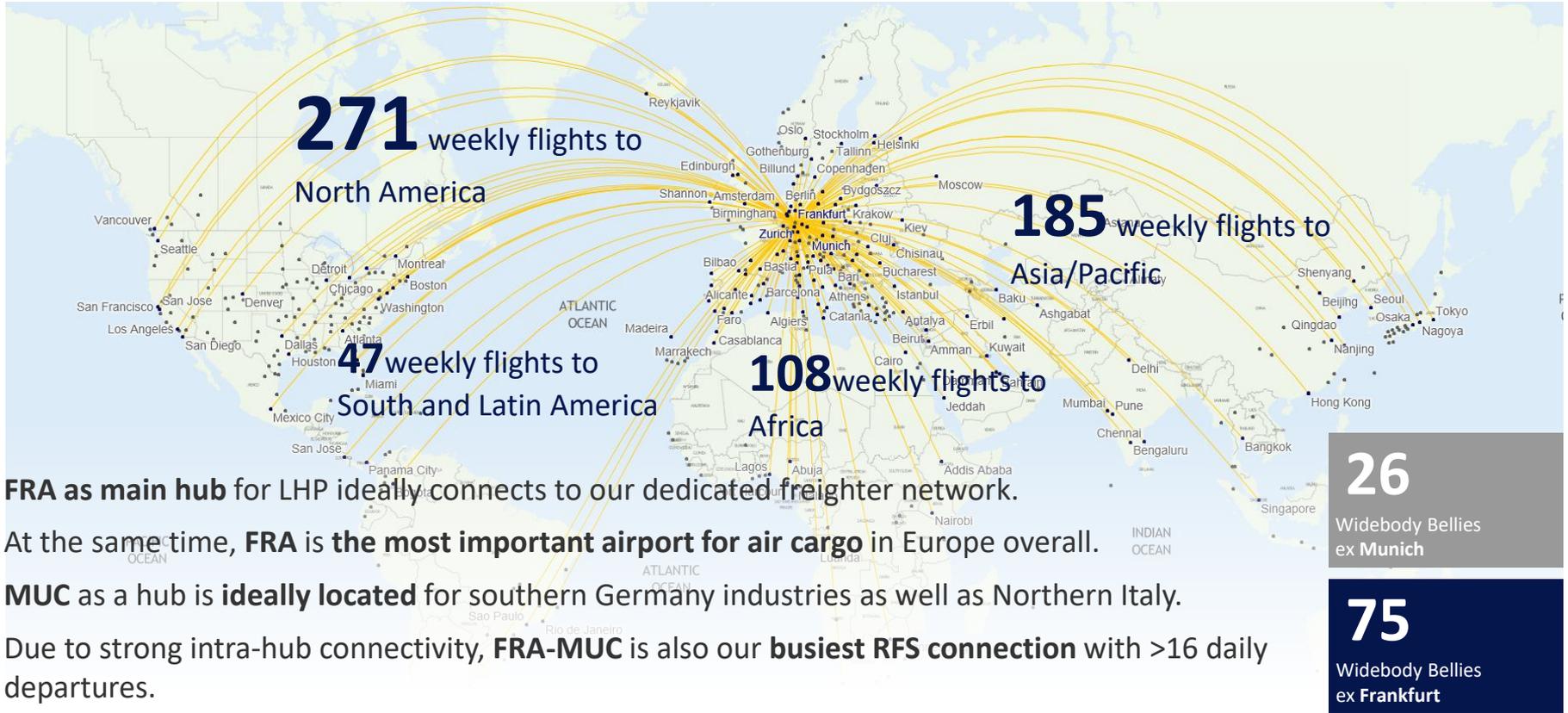
## Platforms and Hubs

<b>19</b> Freighters 12 MD11F, 7 B777F	<b>75</b> Widebody Bellies ex Frankfurt	<b>26</b> Widebody Bellies ex Munich
<b>250</b> RFS-Trucks worldwide daily	<b>11</b> Widebody Bellies ex Vienna	<b>19</b> Widebody Bellies ex CGN, DUS and BRU

## Our Regions and Products, Revenue 2017



# Lufthansa: Connecting the world via FRA and MUC. The backbone of our belly network.



**FRA as main hub** for LHP ideally connects to our dedicated freighter network.

At the same time, **FRA is the most important airport for air cargo** in Europe overall.

**MUC as a hub** is **ideally located** for southern Germany industries as well as Northern Italy.

Due to strong intra-hub connectivity, **FRA-MUC** is also our **busiest RFS connection** with >16 daily departures.

# Austrian Airlines: Strong in central-south eastern Europe, fast and efficient in VIE. We connect trunk routes between Europe, USA and Asia.



OS Destinations  
Primary Air Freight  
Hubs in **red**

**JFK** (New York)

EWR (Newark)

IAD (Washington, DC)

YYZ (Toronto)

**ORD** (Chicago)

**MIA** (Miami)

**LAX** (Los Angeles)

**NRT** (Tokyo)

**PEK** (Beijing)

**PVG** (Shanghai)

**HKG** (Hong Kong)

BKK (Bangkok)

## OS Widebody Fleet

6x Boeing 767-300ER



6x Boeing 777-200ER



- Fleet Growth of **+1 777-200ER**

- OS return to **Tokyo**, completing Japan network



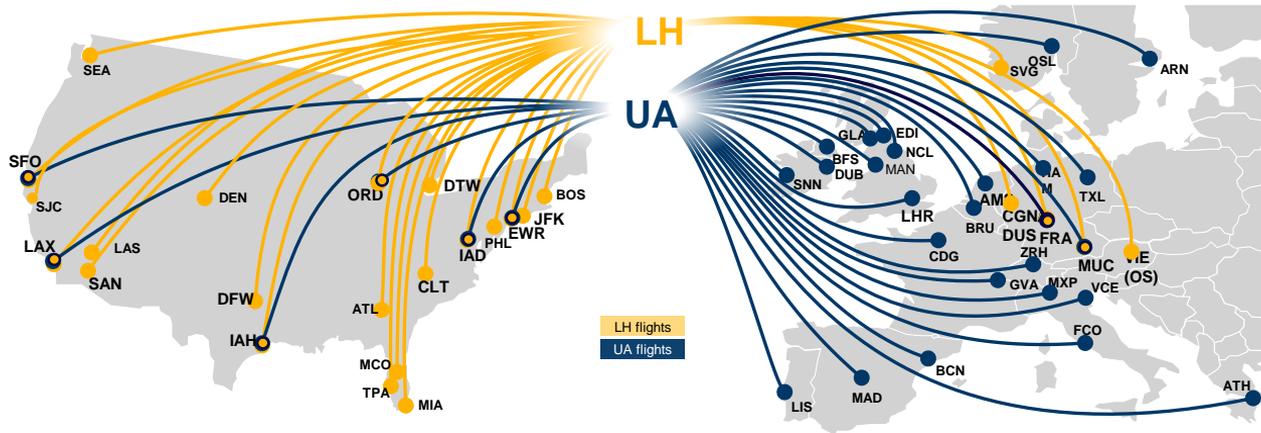
# Continued development of joint venture partnerships Cooperations in three major air cargo markets enhance our network.



# Example UA: United Cargo and Lufthansa Cargo are bringing together our best to offer more and better shipping options.



- United Cargo and Lufthansa Cargo are partners on routes between the US and Europe
- Both companies align on certain activities, such as sales and booking processes as well as handling procedures
- Customers benefit from access to both networks and much more



## UA brings in (weekly):

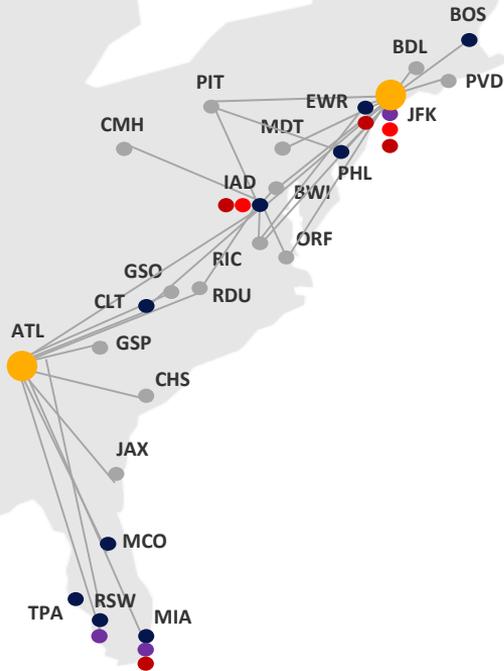
- > **500** transatlantic flights to > **25** European destinations
- > 8,000 feeder flights between **90** U.S. stations

## LH brings in (weekly):

- > **300** transatlantic flights to > **22** US destinations
- > 4,000 feeder flights between > **180** European stations



# Example US East Coast – full spectrum from freighter connection to main hubs to the capillaries of our Road Feeder Service (Trucks) network.



## Belly partners span our network:

- Lufthansa** to Frankfurt, Munich
- Eurowings** to Cologne, Düsseldorf, Munich
- Austrian Airlines** to Vienna
- Brussels Airlines** to Brussels

## When demand exceeds capacity:

- Lufthansa Cargo** to Frankfurt

## To connect and reach where the freight is:

Road Feeder

# Subproblems of (cargo) airline scheduling process



Renew and strengthen our core business

## NETWORK DESIGN

Determine set of flight legs  
Which market?  
How many frequencies?

## FLIGHT SCHEDULING

Which departure and arrival time?

## FLEET ASSIGNMENT

Which aircraft type should be assigned to each flight legs?

## AIRCRAFT ROTATION

Assignment of rotations to individual aircraft

## CREW SCHEDULING

Assign work schedules to all crew members

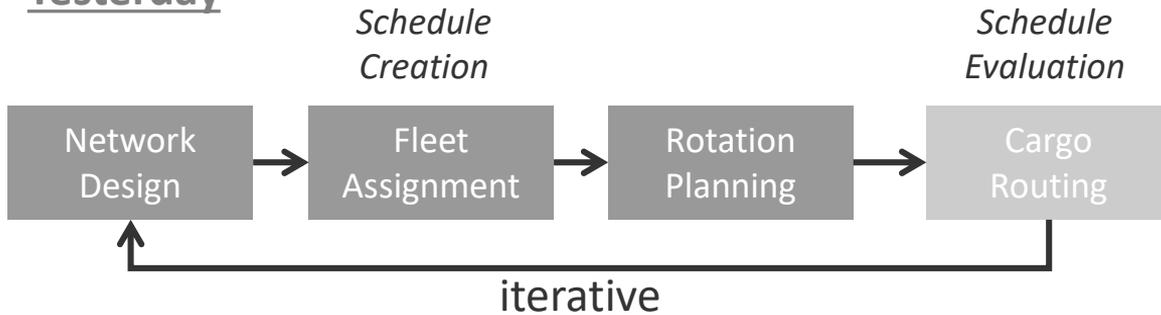
## CARGO ROUTING

Which shipments should be transported on which flight leg

# Basis of the new approach is an integrated optimization approach with as many sub-problems as technically possible.

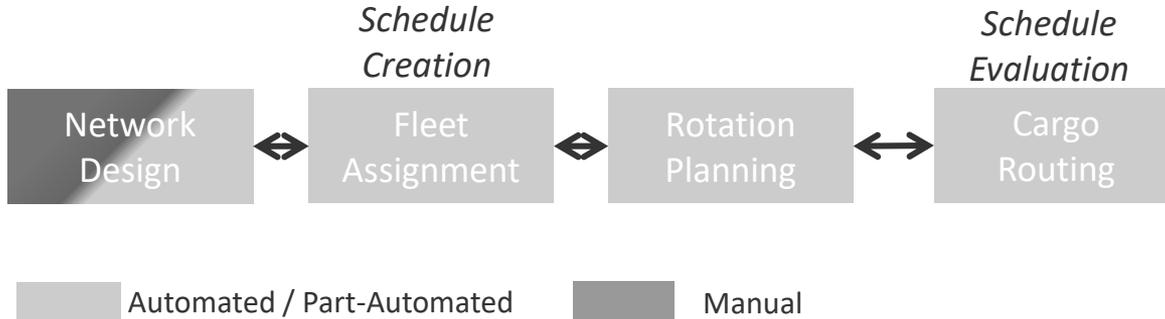


## Yesterday



$$\begin{aligned} \max \quad & \sum_{l \in \mathcal{L}} \sum_{od \in \mathcal{OD}} \sum_{i \in F_{od}} y_{od,l} p_{od,l}^i \lambda_{od}^i \\ \text{s.t.} \quad & \sum_{od \in \mathcal{OD}} \sum_{i \in F_{od}} p_{od,l}^i \lambda_{od}^i \leq u_l \quad \forall l \in \mathcal{L} \\ & \sum_{i \in F_{od}} \lambda_{od}^i \leq q_{od} \quad \forall od \in \mathcal{OD} \\ & \lambda_{od}^i \geq 0 \quad \forall i \in F_{od}, od \in \mathcal{OD} \end{aligned}$$

## Today



$$\begin{aligned} \max \quad & \sum_{n \in N} \sum_{e \in \delta^+(q(n))} r_n v_n x_{e,n} - \sum_{e \in E} \sum_{n \in N_e} c_e^{var} x_{e,n} - \sum_{e \in E} c_e^{fix} y_e \\ \text{s.t.} \quad & \sum_{e \in \delta^-(v)} x_{e,n} = \sum_{e \in \delta^+(v)} x_{e,n} \quad \forall n \in N_e, \forall v \in V \setminus \{q, s\} \\ & \sum_{e \in \delta^+(q(n))} x_{e,n} \leq d_n \quad \forall n \in N \\ & \sum_{n \in N_f} v_n x_{f,n} \leq u_f \quad \forall f \in F \\ & \sum_{f \in N_f} x_{f,n} \leq \sum_{r \in R_f} y_r M \quad \forall f \in F \\ & \sum_{r \in R_{aktiv}(t_{min}(r'), a(r'))} y_r \leq a_{max} \quad \forall r' \in R \\ & x_{e,n} \geq 0 \quad \forall e \in E, \forall n \in N_e \\ & y_r \in \{0, 1\} \quad \forall e \in F, \forall r \in R_e \end{aligned}$$

## Network Design – Schedule seasonalization in-depth look. schedule is tailored to the shipment potentials (O&D).

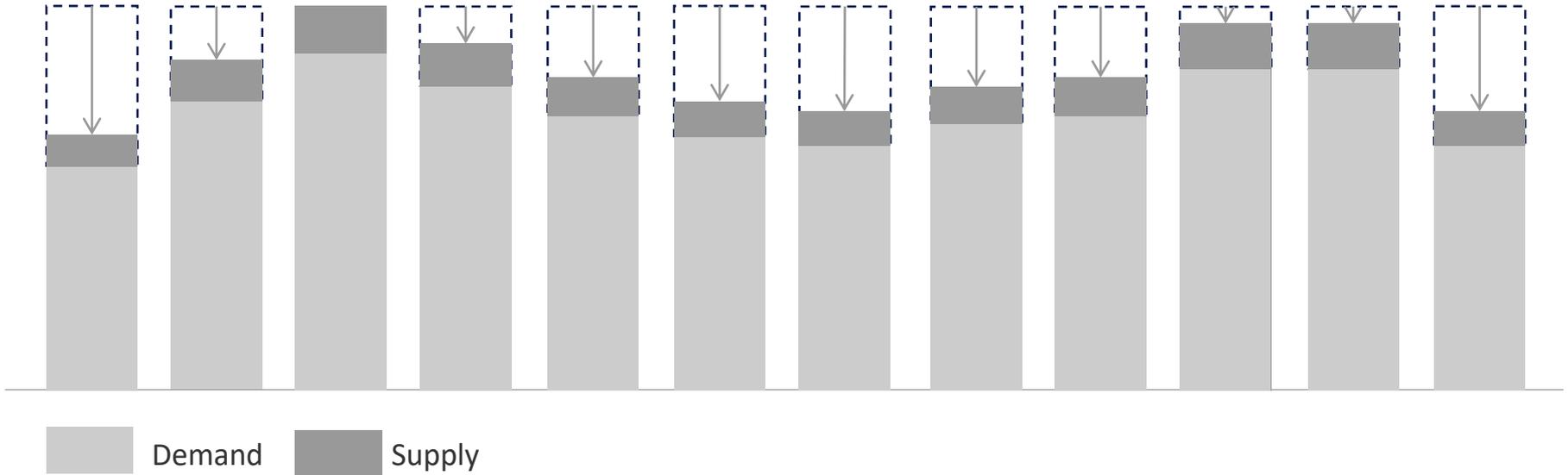
The



During network creation, a full peak schedule is fed into the system.

Based on day-exact and seasonalized O&D potentials, flights are also seasonalized to maximize profit contribution for each single week.

This process is now automated and integrated into the optimization.



## Network Design – Stopover Finding allows to find new optimal routings for a leaner schedule as well as find new routing alternatives.

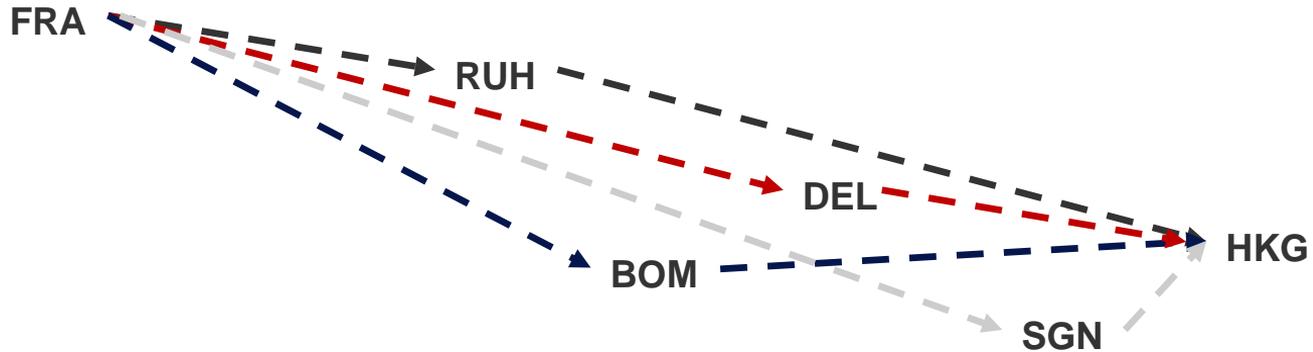


To consistently fill flights, stopovers are often required.

Due to isolated observations on flights however, a global optimum is not found.

Based on maximum detour, the new application will generate a large number of stopover alternatives for certain legs and the optimizer will select the best alternative.

Thus, a base schedule can be fed into the system to keep the schedule as lean as possible. In further examination, an optimal setup of direct and stopover flights can be created.



# The Fleet Assignment problem at LCAG is simple enough to be integrated into the optimization with only two freighter aircraft types.



To support finding the optimal fleet assignment, the network design functionality will be used.

Fleet Assignment is one of the sub-problems tackled by the new application.

To solve it, roundtrips can be flagged as either M1F or 77F. Both alternatives are generated for the subset of flagged flights.

On a global level, an optimal set of flights based on profit is found to assign the correct destinations to the correct aircraft.



# Scenario Capability means to be able to evaluate numerous scenarios at short notice and react to external and internal factors.



The main aim in designing the new application was scenario capability for extended use.

With the new solution it will be possible to:

- evaluate and optimize schedule scenarios in hours instead of weeks
- evaluate the optimal number of freighter aircraft
- build scenarios during the year based on currency shifts/yield changes
- find the optimal freighter/belly share for schedule seasons
- adapt to changes in fuel prices and currency exchange rate

The output produced will contain all information for detailed analysis on:

- optimal cargo routing
- unused potential
- complete sales and production budget
- individual profit contribution for all flights

## In a nutshell, main differences between old and new systems lie between total runtime requirements and greatly extended functionality.



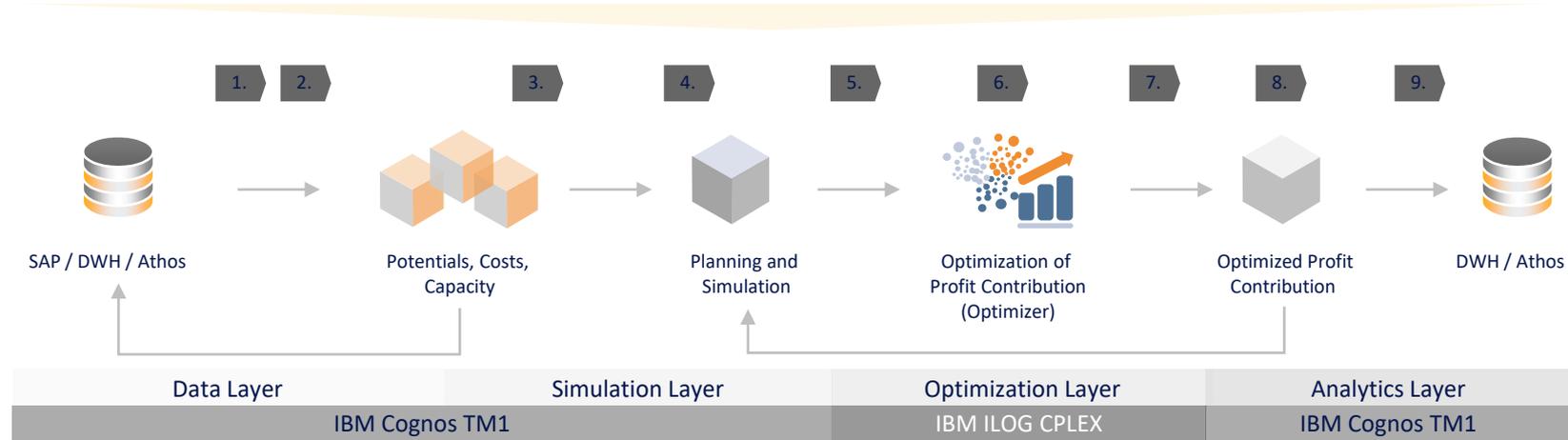
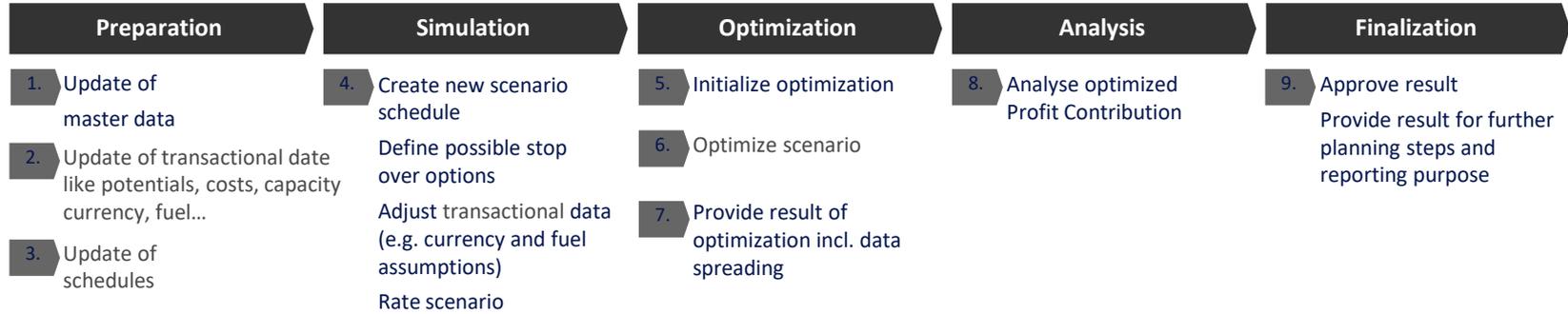
	Old application	New application
Minimum Total Process time	4 weeks	<1 week
Optimization	Heuristic	Exact
Cargo Routing	Automated	Automated
Network Optimization	Manual	Part-Automated
Rotation Planning	Manual	Part-Automated
Fleet Assignment	Manual	Automated
Data Edit	Administrator	User
Traffic Day seasonality	No	Yes
Scenario Capability	No	Yes
Budget Output Integrity	No	Yes
Max Products	3	>3
Platform differentiation	No	Yes
Price-demand function	No	Yes*



## **The potential uses of the new application are greater than currently planned.**

- Potential Data needs to be improved for the new functionality to fully be put to use
- Usage of O&D Forecasting model based on eAnalytics is currently evaluated
- Longer-term, a market model, at least as input, which includes competitor capacity and the whole freight market would be a logical next step.
- A usage for short-term schedule adjustments could be evaluated in the future, combining pure forecasted demand with already known bookings and integrating a broader picture in the decision of whether to operate a flight or not.
- Cargo Routing Information produced by optimizer could be used for production planning/forecasting in greater extent (regular runs).
- By design, a usage for evaluating fleet scenarios would be possible and will be further looked at after implementation.

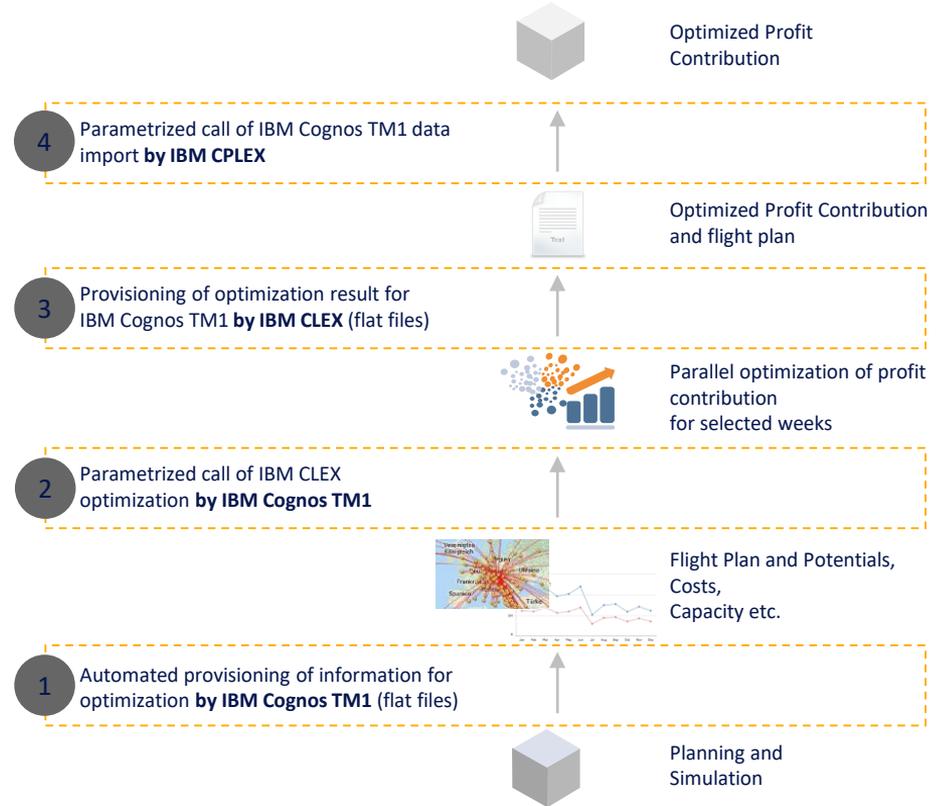
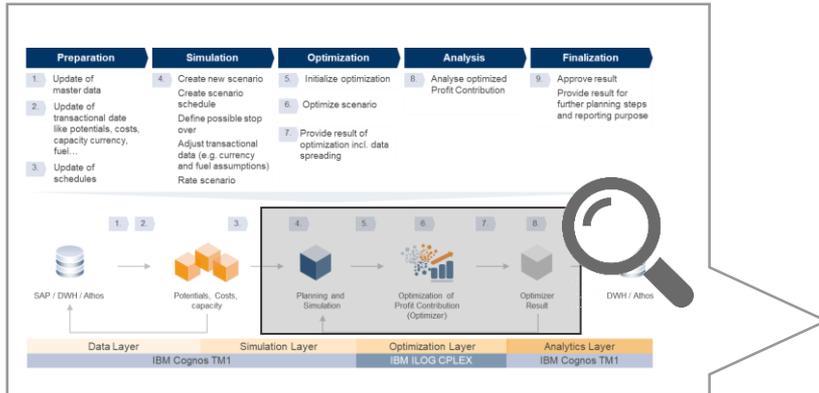
# Workflow and Use Cases



# Integration of IBM Cognos TM1 and IBM CPLEX



- Environment exists of two Virtual Machines dedicated to IBM Cognos TM1 and IBM CPLEX
- IBM Cognos TM1 and IBM CPLEX are integrated based upon flat files
- Whole data flow is managed by IBM Cognos TM1 and IBM CPLEX
- Logging information can be reviewed in IBM Cognos TM1



# Start cockpit of the web based application designed following the process sequence (first level)



IBM Cognos TM1 Web

**Casanova 2.0 - Start Cockpit**

Preparation	Initialization	Optimization	Analysis and finalization	Administration
Dimension Import	<input checked="" type="checkbox"/> Scenario Creation	<input checked="" type="checkbox"/> Optimization	<input checked="" type="checkbox"/> Export	<input checked="" type="checkbox"/> Clean-Up
Set ID Editor (and Currency)	<input checked="" type="checkbox"/> Scenario Assignment	<input checked="" type="checkbox"/>		
Data Import	<input checked="" type="checkbox"/> Scenario Preparation	<input checked="" type="checkbox"/>		
Schedule Import	<input checked="" type="checkbox"/> Stop Over / EQT / Option	<input checked="" type="checkbox"/>		
	<input checked="" type="checkbox"/> Scenario Rating	<input checked="" type="checkbox"/>		

**Overview of recent transactional data manipulation**

Start date:  End date:

Cube	Updated	Updated by	Status	Set ID	Remark



# The single working steps follow the same „sequence“ logic in the second level

IBM Cognos TM1 Web

01 Startcockpit | 02 Dimension Import | 03 Master Data

## Casanova 2.0 - Dimension Import U061725 - 14.06.2018

[<< Startcockpit](#)

Origin and destination dimensions	No. of records processed: 17760
Source: DWH	Updated: 2017-08-15 12:04
Select file from file list (10 x 10 matrix):	Updated by: U061725
Select file from file list (deputy):	Last used file 10 x 10 Matrix: tr\2_10x10 Matrix_Deputy zu 10x10_Budget 2018_Update_260717.csv
Remark:	Last used file Deputy: \incoming\Flatfile\Airport\Deputy\1_RegionenSet_Update_260717.csv
<a href="#">Update file list</a> <a href="#">Update Dimension</a>	Remark: Update 170815

SalesOrgExport dimension	No. of records processed: 639
Source: DWH	Updated: 2018-02-22 15:11
Remark:	Updated by: U524896
<a href="#">Update Dimension</a>	Remark: Neue Sales Org 2018

Product dimension	No. of records processed: 27
Source: DWH	Updated: 2017-02-08 17:42
Remark:	Updated by: U153041
<a href="#">Update Dimension</a>	Remark: Test SDE Issue 673999

Mileage prorata table dimension	No. of records processed: 2669530
Source: DWH	Updated: 2017-01-23 15:41
Remark:	Updated by: U153042
<a href="#">Update Dimension</a>	Remark: test CPO

Time	No. of records processed: 13148
Select file from file list:	Updated: 2017-01-23 14:39
Remark:	Updated by: U153042
<a href="#">Update Dimension</a>	Last file: \\SW-FRALCAG-CAD1e\casanova\interface\incoming\Flatfile\Time\Time.csv
	Remark: Test CPO

### Overview

Start date: 15.05.2018	End date: 14.06.2018	<a href="#">Refresh</a>
------------------------	----------------------	-------------------------

Dimension	Updated	Updated by	Status	Number of records	Remark
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# Network design to generate alternative routings and/or different options for fleet assignment



IBM Cognos TM1 Web WI

01 Startcockpit | 02 Dimension Import | 03 Master Data | 05 Schedule Import | 06 Scenario Creation | 07 Scenario Assignment | 09 Stopover Change

## Casanova 2.0 - Processing code, Stop over, EQT change

U061725 - 14.06.2018

[<< Startcockpit](#)   
 [<< Scenario Creation](#)   
 [<< Scenario Assignm](#)

### Adjust flight properties

Scenario	Budget 2018 - Loop3 (SCENARIO-20171009-0001)	Description	Budget 2018 - Loop3 (SCENARIO-20171009-0001)	Validity	01.01.2018 - 31.12.2018
Schedule type	LCAG	Updated	2017-10-09 15:36	Status	Applied information successfully.
GFP	Freighter	Updated by	U061725	MPA L2 %	0,50%
Calendar week	2018CW05	Remark	Loop 3 Update LCAG Plan		
Trip	All Trips	<a href="#">Refresh</a>			

[Allocate processing code](#)
[Create stopover variant](#)
[Create EQT change variant](#)

Trips, Flights and Legs	Days of operation in specified week							Return code after optimization							Processing code for optimizer							Detour allowance for stop overs (%)							Equipment change flag						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
<b>All Trips</b>																																			
LH 8160 / LH 8161 M1F (23)	1							2							3							0													
LH 8160 FRAJFK M1F (68)	1							2							3							0													
LH 8160 FRAJFK 09201815 M1F (1)	1							2							3							0													
LH 8161 JFKFRA M1F (62)	1							2							3							0													
LH 8161 JFKFRA 20450410 M1F (1)	1							2							3							0													
LH 8164 / LH 8165 77F (19)	1							2							3							0													
LH 8164 FRAATL IAH 77F (1)	1							2							3							0													
LH 8164 FRAATL 13452350 77F (1)	1							2							3							0													
LH 8164 ATL IAH 01500410 77F (1)	1							2							3							0													
LH 8165 IAHFRA 77F (24)	1							2							3							0													
LH 8165 IAHFRA 06101545 77F (2)	1							2							3							0													

# The scenario is rated - all Set ID and premises are taken into account. Everything should be in place now to be optimized



## Casanova 2.0 - Scenario Rating

U061725 - 14.06.2018

[<< Schedule Import](#)
[<< Scenario Creation](#)
[<< Scenario Assignment](#)
[<< Scenario Preparation](#)
[<< Processing, StopOver and EQT](#)

### Allocate sets to scenario

Target scenario	Budget 2018 - Loop3 (SCENARIO-20171009-0001)	Description	Budget 2018 - Loop3 (SCENARIO-20171009-0001)	Validity	01.01.2018 - 31.12.2018
		Scenario ID	SCENARIO-20171009-0001	Status	Applied information successfully.
		Updated	2017-10-09 15:36	MPA L2 %	0,50%
		Updated by	U061725	Remark	Loop 3 Update LCAG Plan

### Define corresponding sets

#### Allocate sets to scenario

Transactional data	New corresponding Set ID	Updated	Updated by	Status	
Payload restricted	Budget 2018 - Loop 2 (SETID-2017)	2017-08-16 19:19	U061725	Import was successful.	<a href="#">Payload restricted overview</a>
Payload standard	Budget 2018 - Loop 2 (SETID-2017)				<a href="#">Payload standard overview</a>
ACMI	Budget 2018 - Loop 1 (SETID-2017)				<a href="#">ACMI overview</a>
RFS	Budget 2018 - Loop 3 (SETID-2017)	2017-10-09 18:38	U061725	Import was successful.	<a href="#">RFS overview</a>
Handling time	Budget 2018 - Loop 3 (SETID-2017)	2017-10-09 18:12	U061725	Import was successful.	<a href="#">Handling time overview</a>
Handling cost	Budget 2018 - Loop 3 (SETID-2017)	2017-10-09 18:10	U061725	Import was successful.	<a href="#">Handling cost overview</a>
Capacity bought	Budget 2018 - Loop 2 (SETID-2017)				<a href="#">Capacity bought overview</a>
Capacity sold	Budget 2018 - Loop 1 (SETID-2017)				<a href="#">Capacity sold overview</a>

[Allocate sets to scenario](#)

### Rate cost cargo legs

#### Export cost cargo

Source scenario	Budget 2018 - Loop3 (SCENARIO-20171009-0001)
Value type	Plan

[Export cost cargo information](#)

#### Import cost cargo

Target scenario	Budget 2018 - Loop3 (SCENARIO-20171009-0001)
File	-

[Update file list](#)

[Import cost cargo information](#)

[Cost cargo overview](#)

#### Rate scenario

[Rate scenario](#)

[View scenario details](#)

# Optimization



## Casanova 2.0 - Optimization

U061725 - 14.06.2018

### Optimize scenario

<< Startcockpit

<< Scenario Rating

Scenario	<input type="text"/>
Starting calendar week	<input type="text"/>
Ending calendar week	<input type="text"/>

Download Optimizer files

Download and optimize

Description  
Updated  
Updated by

Validity  
Status  
MPA L2 %  
Remark

Potential overview

Cost Cargo overview

Currency (plan) overview

Fuel (plan) overview

Capacity bought overview

Capacity sold overview

Payload standard overview

Payload restricted overview

ACMI overview

RFS overview

Handling time overview

Handling cost overview

Scenario overview for optimizer

Combined output overview

Combined spread overview

Other fixcost overview

Charter cost belly overview

Optimization can be directly started or

The files for the optimizer comfortably downloaded and checked before



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**Lufthansa Cargo**  
Networking the world.



## Key numbers of the CPLEX optimizer

Test-Nr. #	O&Ds #	Flussvariablen #	Binärvariablen	Rechenzeit
1	12.687	1.070.297	53	23 min 55 s
2	11.671	1.021.283	66	42 min 42 s
3	13.456	1.199.740	69	54 min 30 s
4	13.456	1.346.096	138	488 min 15 s
5	13.456	1.673.833	213	603 min 53 s

Test 1: KW 07 - variable Rate und Zusatzpotentiale

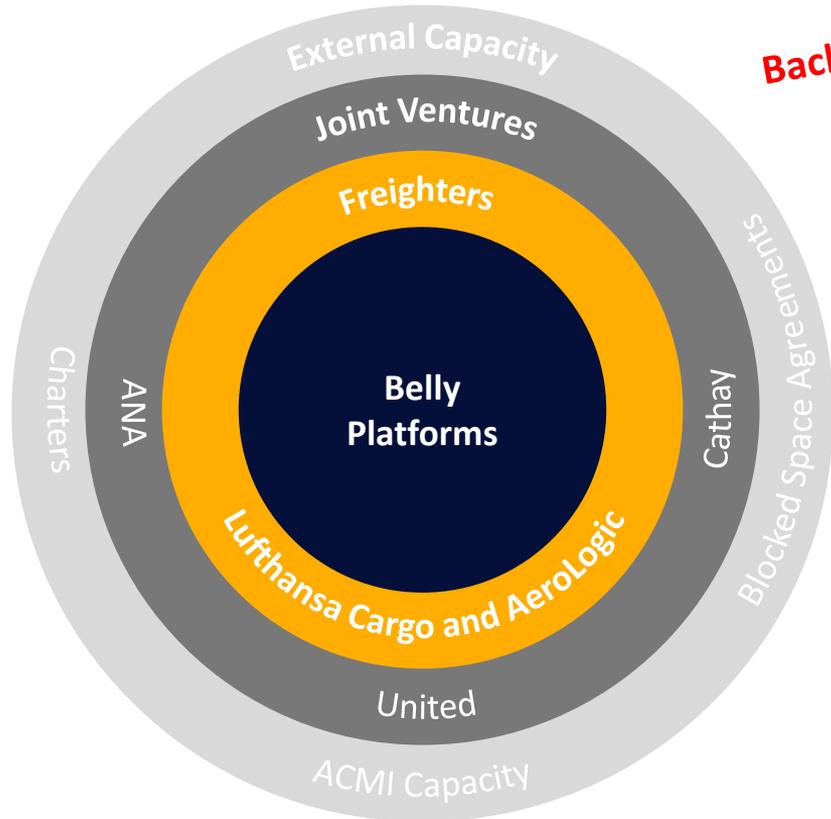
Test 2: KW 06 - variable Rate und Zusatzpotentiale

Test 3: KW 10 - variable Rate und Zusatzpotentiale

Test 4: KW 10 - variable Rate und Zusatzpotentiale (Fleet Assignment)

Test 5: KW 10 - variable Rate und Zusatzpotentiale (Dreiecksflüge)

We are growing our core business with new belly partners and freighters while investing in a better customer offer through joint ventures.



**Back-Up**

**Our core business**

**Lufthansa Group Belly Platforms**

- Lufthansa
- Austrian Airlines
- Eurowings
- Brussels Airlines (from September 2018)

**Freighter Capacity**

- 5x 777 freighters (+2 ordered)
- 2x 777 freighters within AeroLogic
- 12x MD-11F freighters

**Combined with three Joint Venture partners**



**Brussels Airlines:** with its focus on Africa it is an ideal match for Lufthansa Cargo and signals a huge leap in Africa-World air cargo connections.



**BACK-UP**



**SN Widebody Fleet**

4x Airbus A330-200

6x Airbus A330-300



**16 SN Widebody Destinations in Africa**

Dakar (Senegal)	Accra (Ghana)
Banjul (Gambia)	Lomé (Togo)
Conakry (Guinea)	Douala, Yaoundé (Cameroon)
Freetown (Sierra Leone)	Kinshasa (DR Congo)
Monrovia (Liberia)	Luanda (Angola)
Cotonou (Benin)	Entebbe (Uganda)
Ouagadougou (Burkina Faso)	Kigali (Rwanda)
Abidjan (Ivory Coast)	Bujumbura (Burundi)

## Eurowings: Long-haul fleet grows to 10 AC. DUS replaces CGN, MUC introduced this Summer. Focus on North America & Caribbean.



### BACK-UP Summer Schedule 2018 Frequencies



- Lufthansa Cargo **only** transports cargo on **long-haul** fleet, the intercontinental network.
- Eurowings long-haul network is dominated by **secondary and tertiary** cargo markets.
- Long-haul ops is **divided between CGN, DUS and MUC**.
- CGN ops will **migrate to DUS**.
- **Connectivity** is provided by **RFS** connex to larger markets with less time-critical freight.

Region	CGN	DUS	MUC
Asia	1/7		2/7
North America	4/7	12/7	4/7
Caribbean	11/7	6/7	4/7
Africa	2/7		4/7
<b>Total</b>	<b>18/7</b>	<b>18/7</b>	<b>14/7</b>

# The Lufthansa Cargo Freighter fleet consists of own-operated MD-11Fs as well as 777Fs operated in LH and AeroLogic colors.



Our **MD-11F** fleet of **twelve** production freighters offers a net payload of 85 tons.

MD-11F range makes it ideal match for North Atlantic and South Asia routes.

**Five 777F freighters** with >100 t payload and very high productivity run our double-daily freighter network to North and East China as well as daily frequencies to Japan and Korea.

**Two 777F freighter** equivalents operated by our operations partner **AeroLogic** are flown like our own capacity – they offer additional weekend peak uplift to the Americas and India.

Back-up

