29th Congress of the International Council
of the Aeronautical Sciences
St. Petersburg, Russia; September 7-12, 2014

ANALYSES ON A CIVIL AIR TO AIR REFUELING NETWORK IN A TRAFFIC SIMULATION

Fabian Morscheck
DLR

Keywords: *air to air refueling, fuel saving, traffic simulation, cruiser feeder operations*

Abstract

The project REsearch on a CRuiser Enabled Air Transport Environment (RECREATE) is about the introduction and airworthiness of cruiser-feeder operations for civil aircraft. Cruiser-feeder operations are investigated as a promising pioneering idea for the air transport of the future.
The top level objective of the project is to demonstrate on a preliminary design level that cruiser-feeder operations (as a concept to reduce fuel burn and CO_2 *emission levels) can be shown to comply with the airworthiness requirements for civil aircraft.*
(The 42-month RECREATE project research receives funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 284741.

This publication reflects only the authors' views. The European Union is not liable for any use that may be made of the information contained therein.)

Air-to-air refuelling operations are an example of this concept. Currently Air-to-air refuelling operations are primary used to extend range of aircrafts in military operation. However some research has been done in the past to estimate fuel saving capabilities of air-to-air refuelling in both military and civil operations. Most of these estimations give highly positive results on the fuel saving capabilities. Nevertheless these results mainly based on a small number of optimised cases.
As part of the primary design in the RECREATE project this paper will discuss air-to-air refuelling operations in a traffic scenario based on Eurocontrol-Data containing one day of traffic over Europe. The effects of different design parameters for the participating aircrafts and the underling air to air refuelling network will be the centre of discussion in this paper.

1 Nomenclature

$\dot{M}_{fuel}$	FUELFLOW
M_{fuel}	FUEL USED (OVERALL)
$M_{fuel\,cruise}$	CRUISER FUEL USED DURING CRUISE LEVEL FLIGHT AS A FUNCTION OF MASS, X-FACTOR AND THE FLOWN DISTANCE
$M_{fuel\,takeoff}$	FUEL USED IN THE TAKEOFF PHASE
$M_{fuel\,landing}$	FUEL USED IN THE LANDING PHASE
$M_{Cruiser}$	CRUISER MASS
M_{Feeder}	FEEDER MASS
X	EFFICIENCY FACTOR X (DEFINED IN FORMULA 2)
d_{1-2}	RANGE BETWEEN POINT 1 AND 2
v	CRUISE LEVEL AIRSTREAM VELOCITY
$\frac{L}{D}$	LIFT OVER DRAG RATIO
sfc	SPECIFIC FUEL CONSUMPTION
$n_{refuelingoperations}$	NUMBER OF REFUEL OPERATIONS PER TANKER

2 Idea – Architecture

The general idea in fuel saving through air to air refueling is to divide the flight range in two or more smaller ranges and refuel on air between them. Thus the aircraft need less fuel for each step. Less fuel then leads to weight reduction which results in less fuel burn over the whole distance.

On the other hand the feeder aircraft will burn fuel while refueling the cruiser. Earlier studies [1-3] have shown that the fuel saving with air to air refueling is quite low if the refueled aircraft is the same aircraft that could fly the complete distance without refueling.

To save fuel the lower distance between the refueling points is used to fly the distance with a lower range aircraft. As such an aircraft is designed to carry less fuel with it the whole aircraft is less heavy then a long range aircraft for the same amount of passengers. Studies have shown that with this method fuel savings of up to 20% are possible [1-3].

As it is quite unlikely that cruiser will fly multiples of their range in day to day business the main task of a traffic simulation is to determine realistic fuel savings in an air traffic network. Furthermore the traffic simulation could show difficulties and aspects of an air to air refueling network which will not show up in single flight analysis.

To achieve these functions the Traffic Simulation needs to make some choices between optimal refueling condition and realistic compromises.

In the first step the prepared scenario data will be loaded including the connections, the take of time, the aircraft time and the available feeder bases. In this paper one day [5] of Eurocontrol traffic will be used as basis for the Scenario. The aircrafts from the scenario data will be replaced with RECREATE aircrafts. As the parameter of the RECREATE aircrafts could change between simulation runs the actual replacement could not be done within the scenario design.

In the next step a first fuel consumption for the reference aircraft will be estimated. The reference aircraft uses the same efficiency as the refueled aircraft and flies on great circle rout to the target airport. The calculated fuel consumption will be used to analyze the fuel savings from the air to air refueling maneuver in the following steps. Furthermore the maximal achievable fuel savings will be calculated in this step. For this calculation the cruiser will fly on great circle routes directly to their destination. They will be refueled at their optimal refueling position (in the middle of the route or at a third/quarter if more than one refueling operation is necessary). To calculate the fuel burned by the feeder aircraft a feeder base near the refueling position will be assumed.

In the following step the cruiser routes will be optimized to their fuel savings. Unlike to the maximal achievable fuel saving calculations the feeder bases of the scenario will be used in this calculation. The feeder base selection will be described in the feeder section of this paper [Chapter 3.1]. To find an optimal refueling position the meeting point between feeder and cruiser could be moved freely until the spent fuel for both aircrafts is minimal. The fuel consumption calculated in this step is the minimal achievable fuel consumption for this connection and the fixed feeder bases. The feeder situation is optimal but unrealistic.

To get more realistic feeder fuel consumptions is the intention of the next step. Thus the refuel requests on one feeder base are scheduled to feeder aircrafts. The scheduling routine balances between short feeder routes and occupied feeders. These calculations give not only more realistic feeder fuel consumption but also a number of necessary feeder aircraft at each feeder base. Furthermore these calculations result in full trajectories for the feeder and the cruiser. Thus numbers like the feeder workload over the day or the runway traffic on the feeder base could be analyzed.

2.1 Cruiser optimization

The following chapter will describe the Cruiser optimization routine. As the cruiser routes will be optimized on their full consumption the fuel calculations are the main part in the optimization routine. In the Calculation the cruiser will fly on great circle routes between start and end position as well as any refueling position calculated in the optimization routine. The fuel consumption with n refueling operations is calculated with the following formulas.

The current fuel burn calculates as:

$$\begin{aligned}\dot{M}_{fuel} = \Bigg[& \frac{M_{aircraft}(s)}{\frac{L}{D}} \\ & + g\, M_{aircraft}(s)\sin(\gamma) \Bigg] * sfc\end{aligned}$$

With

$$M_{fuel} = \int_{s_0}^{s_1} \dot{M}_{fuel}(s)\, ds$$

and

$$X = \frac{v\,\frac{L}{D}}{sfc}$$

Follows

$$\begin{aligned} & M_{fuel} \\ & = M_{fuel\,takeoff}(M_{cruiser}, X_{cruiser}) \\ & + \sum_{2}^{n_{max}-1} \Big[M_{fuel\,cruise}\big(M_{cruiser}, X_{cruiser}, d_{p(n-1)-pn}\big) \\ & + \Big(M_{fuel\,takeoff}\big(M_{feeder}, X_{feeder}\big) \\ & + M_{fuel\,cruise}\Big(M_{feeder}, X_{feeder}, \big(d_{base-pn} \\ & + d_{refuel} + d_{p(n+1)-base}\big)\Big) \\ & + M_{landing}\big(M_{feeder}, X_{feeder}\big)\Big) \\ & /n_{refueling\,operations} \\ & + M_{fuel\,cruise}\big(M_{cruiser}, X_{cruiser}, d_{p(n+1)-p(n+2)}\big)\Big] \\ & + M_{landing}(M_{cruiser}, X_{cruiser}) \end{aligned}$$

The optimization routine will search for all reasonable combinations of feeder bases. A reasonable connection as distances between the feeder bases within the combined range of feeder and cruiser aircraft. It also lies in the general direction to the target aircraft.

In the next step the optimal refueling positions for each possible route will be calculated. The refueling position indicates the rendezvous point between feeder and cruiser. After this point both aircrafts will fly towards the next waypoint of the cruiser for the next 20 minutes (time of the refueling maneuver). The positions could be moved freely and separate from each other. They will be moved as long as a new position generates less fuel consumption. The optimization ends when no new position in a minimal distance of 1 nm generates less fuel consumption.

The connection with the lowest fuel consumption will be used even if the connection is the direct route without air to air refueling.

2.2 Feeder routing

After the refueling positions have been found the information will be used at the feeder bases to plan the feeder mission from this base. The feeder mission plan is designed to give each feeder aircrafts enough refueling targets to reach the maximal number of refueling operations for each feeder. Also plan tries to keep the number auf necessary feeder low as well as the flown distance of each feeder.

For the first refueling operation of the day the first feeder will be scheduled. In all subsequent refueling operations the distance and time to the rendezvous location from the last scheduled location of each feeder will be calculated. Thereafter the feeder will be scheduled on the refueling mission due the following criteria:

- The feeder with the closest distance in time and space will be chosen for the refueling mission. In the normal operation mode the cruiser time is fixed. The Feeder routing could include slight changes in the cruiser schedule if this would allow a better located feeder to execute the refueling mission.

- Feeder already airborne will be preferred. Thus Feeders who have already performed a refueling mission will more likely be scheduled a following refueling mission than a feeder from the feeder base.

- Airborne Feeder without a refueling mission for a defined timespan will be send back to the feeder base.

- After refueling the maximal number of Cruiser a Feeder will return to the Feeder base.

- Returned Feeders will be stay at the Feeder base for a defined timespan while they will be refueled and prepared for the next mission.

The calculation of the Feeder routes and schedules also defines the number auf necessary Feeder at the Feeder base.

2.3 Input parameters

The earlier described route calculation methods need some Parameters for their calculation. The following will describe those parameters that will be varied between the different simulations:

X-Factor:

The X-Factor determinates the aircrafts efficiency and is defined as the aircraft velocity multiplied with the lift over drag ratio divided by the specific fuel consumption (X = V L/D /sfc). In the basic configuration the cruiser will be calculated with an X-Factor of 18500 nm and the Feeder with an X-Factor of 14000 nm.

Design Range:

The Cruiser design range determinates the distance the cruiser is allowed to fly until a refueling is necessary. The design range also determinates the cruisers weight as more fuel for longer distances will require more structure to hold this fuel. Apart from the basic cases of 2500nm and 3000 nm cruiser the cruiser masses are just rough estimations. The calculated weight is used to calculate the fuel consumption.

Duration of the refueling operation:

The duration of the refueling operation includes the entire phase when the feeder and the cruiser fly along the same track. The time spend in the refueling operation is a huge part in the flight plan of the feeder. With less time spend in the refueling operation less fuel will be burned by the feeder. Furthermore the feeder will stay closer to the feeder base with shorter refueling operations. The default duration of the refueling operation is 20 minutes.

Maximal Feeder-base distance

The maximal feeder base distance is not the same as the feeders design range. It has no effect on the feeder size and only limits the feeder to an area around the feeder base. This limitation keeps the refueling position in a fixed area. In this way feeder for more refueling operations could shorten their routes.

3 Results Transatlantic Scenario

3.1 Feeder Base selection

As the number of feeder bases theses bases should be able to satisfy most of the connections in the scenario. Thus the feeder Bases will lie at position close to the cruiser routes and their optimal refueling position. Presuming the feeder stays close at the feeder base lines with the same fuel saving results could be drawn around the optimal fuel saving position and along the direct cruiser routes as shown in picture 1.

Fig. 1 direct routes in the Transatlantic Scenario

The optimal refueling position and with it possible areas for Feeder bases depend on the cruiser design range. Picture 2 shows the optimal refueling position for cruiser with 2500nm and 3000nm range.

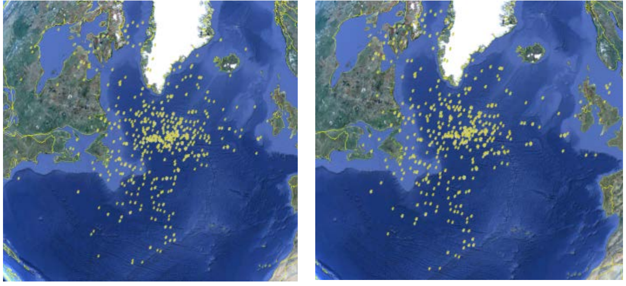

Fig. 2 optimal refueling position for 2500nm cruiser (left) and 3000nm cruiser (right)

In both cases most of the optimal refueling positions lie over the Atlantic in an area south of Greenland between Newfoundland and Ireland. The very small difference between the two cases makes it easier to select feeder bases. Unfortunately the best feeder base location lies on the ocean. Thus the first feeder bases in the transatlantic Scenario are placed around the north Atlantic. Picture 3 shows theses four basic feeder base at Shannon (Ireland), Keflavik (Island), Kangerlussuaq (Greenland) and Gander (Newfoundland).

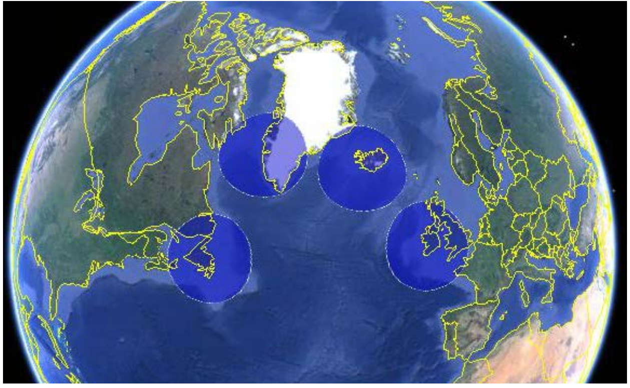

Fig. 3 500 nm radius around the feeder bases at Shannon (Ireland), Keflavik (Island), Kangerlussuaq (Greenland) and Gander (Newfoundland)

In the first test simulation the feeder base at Gander was the most used feeder base. Thus it was reasonable to at a second feeder base in the same area at goose bay. As this feeder base lies more in the north it also serves routes between Europe at the great lake area better than the one at Gander. A sixth feeder base has also been added on the Azores (Lajes) to serve more southern routes from south Europe or the Caribbean area. The last two feeder bases have been added to increase the fuel savings on the routes to east Europe and the American west coast. These feeder bases lie at Churchill Airport in Canada and in Chisinau in the Republic Moldavia.

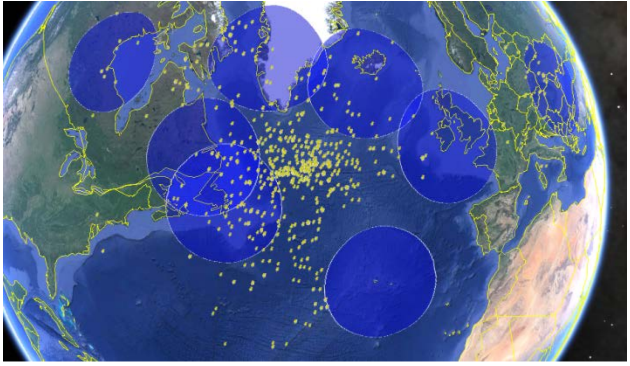

Fig. 4 500 nm radius around the feeder bases at Shannon (Ireland), Keflavik (Island), Kangerlussuaq (Greenland) ,Gander (Newfoundland), Goose Bay (Canada), Lajes (Azores), Churchill Airport (Canada) and Chisinau (Republic Moldavia)

3.2 Savings

In the following mainly the fuel savings for the overall system will be presented and analyzed. All simulations will use the Transatlantic Scenario with the Feeder bases described in the previous chapter. For theses simulation a single parameter will be varied (or two if the parameters are linked) all other parameters will be kept in the default state.

3.2.1 Feeder size variation

In the Traffic Simulation the fuel consumption will be calculated at 3 different detail level of the Simulation. The first fuel calculation assumes Feeder bases close to the optimal refueling position while the cruiser use a direct route to their destination. Also the feeder from this Base will use optimal routes as described in the optimization routine. The second fuel result will use the eight feeder bases to calculate fuel optimized routes for the cruiser will the feeder fuel calculation remains optimal. In the final fuel calculation cruiser and feeder will have completed matched routes.

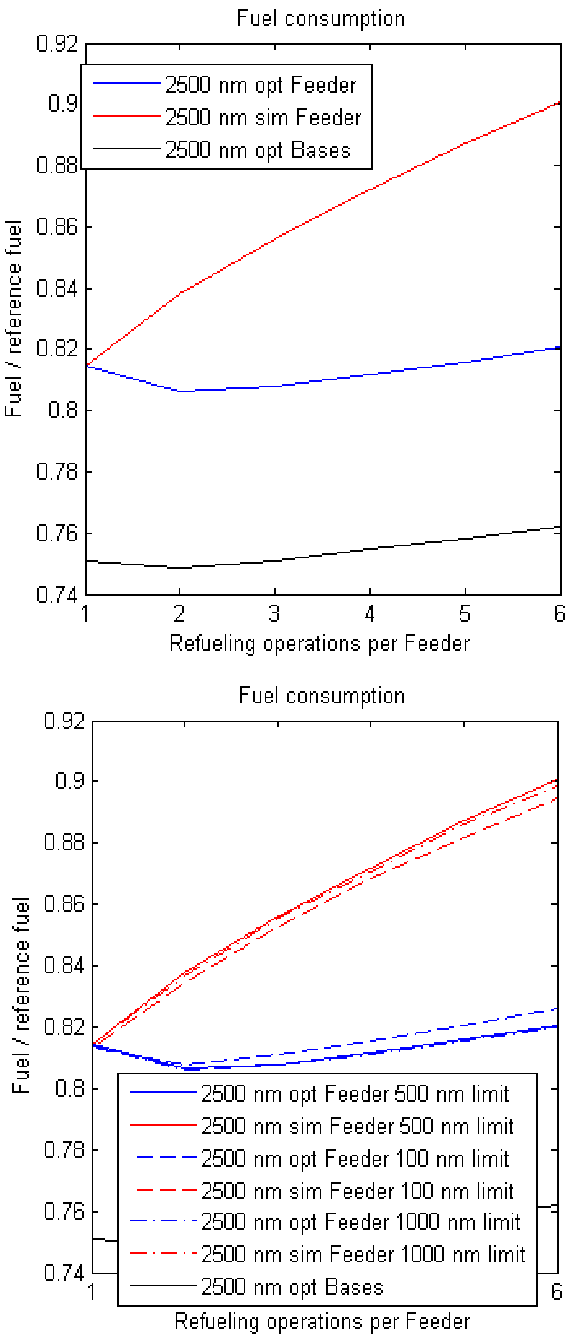

Figure 5 Fuel savings with different Feeder sizes in the Transatlantic Scenario and feeder limitations (below)

Figure 5 shows on the left side the fuel consumption in a transatlantic scenario with 2500 nm cruiser design range and a 500 nm limit around the feeder base for the refueling operations. The curves for the optimal bases case and for the optimal feeder case show a similar behavior with an optimum at two refueling operations per feeder. Nevertheless the not optimal feeder base position and the limitation two eight feeder bases costs around 6.5 % of the theoretic achievable fuel savings. With simulated feeders the one refueling per feeder configuration gives the best results while the losses in fuel savings steadily grow with more refueling operation per feeder. Two refueling operations per feeder generate a loss of around 3% in fuel savings compared to the optimal feeder case. The losses grow up to 8% with 6 refueling operations per feeder.

On the right side the Figure shows the results of the same scenario with an additional variation of the refueling area limitation. It could be seen that limitations worsen the optimal feeder case while a limitation very close to the feeder case betters the results. On the other hand these changes on fuel savings are very low. The variation on these limitations will lie under focus in a later chapter.

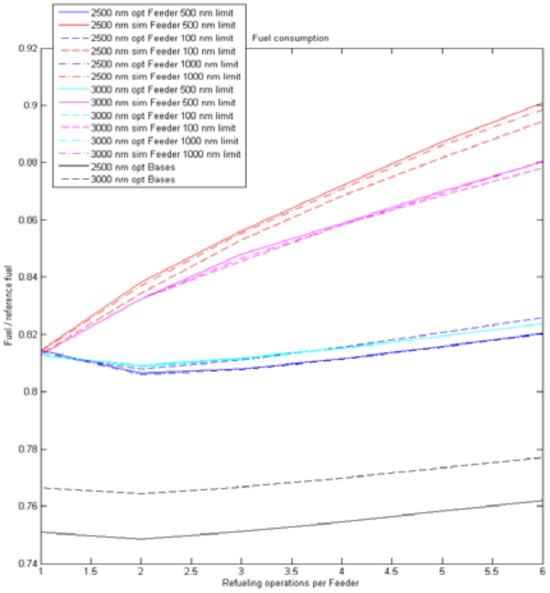

Figure 61 Fuel savings with different Feeder sizes, feeder limitations and cruiser ranges in the Transatlantic Scenario

In Figure 6 the results for a 3000 nm cruiser have been added. The curves for the new cruiser ranges show a similar behavior as in the 2500 nm cruiser case. Two refueling operations per Feeder give again the best results for the optimal base case and the optimal feeder case. While the optimal feeder case gives only slightly lower results in fuel saving the optimal base results give about 2% lower fuel savings than the 2500 nm case. Simulated feeders with more than one refueling operation per feeder give even better results in fuel savings than in the 2500 nm cruiser case. In a later chapter the cruiser range variation will be shown in more details.

3.2.2 Feeder efficiency variation

In this chapter the Feeder efficiency defined in the Feeder X-Factor (quote XX) will be analyzed. The Simulation uses the eight feeder base Transatlantic Scenario with a 3000 nm cruiser. The cruisers X-Factor is 18500 nm.

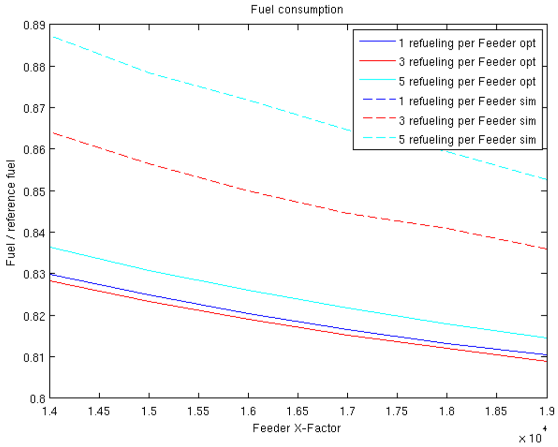

Figure 72 Fuel savings with different Feeder X-Factors

Figure 7 shows the fuel savings for Feeder X-Factors between 14000 nm (the defined case) and 19000 nm. Also the results show the optimal feeder case and the simulated feeder case for Feeder with one, tree and five refueling operations per Feeder. As expected the fuel savings grow with higher Feeder X-Factors. Also the different numbers of refueling operations per feeder show the same behavior for all X-Factors. The differences between optimal feeder and simulated feeder stay nearly constant over all Feeder X-Factors. In the optimal Feeder cases the fuel savings grow up to 2% and in the simulated feeder cases up to 3 %. As the feeder fly longer distances in the simulated case the Feeder efficiency has a higher effect on the fuel savings in those cases.

3.2.3 Cruiser efficiency variation

In this chapter the Cruiser efficiency defined in the Feeder X-Factor (quote XX) will be analyzed. The Simulation uses the eight feeder base Transatlantic Scenario with a 3000 nm cruiser. The Feeder X-Factor is 14000 nm.

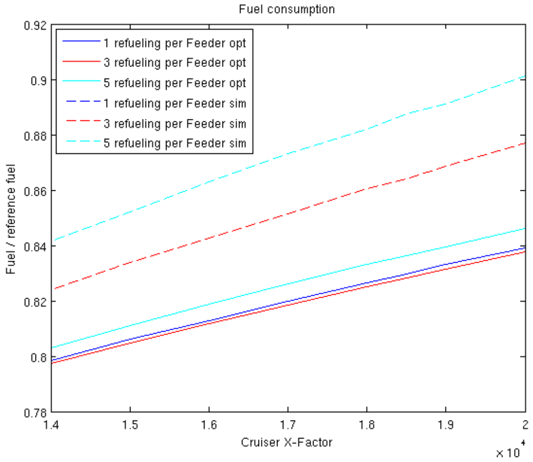

Figure 83 Fuel savings with different Cruiser X-Factors

Figure 8 shows the fuel savings for Cruiser X-Factors between 14000 nm (18500 is the defined case) and 20000 nm. Also the results show the optimal feeder case and the simulated feeder case for Feeder with one, tree and five refueling operations per Feeder. With grow in cruiser efficiency the simulations calculates lower fuel savings for all cases. In the optimal cases the fuel savings decrease around 4% and 5% in the simulation.

Together with the Feeder efficiency variation it could be seen that the fuel savings grow if the feeder becomes more efficient compared to the cruiser while a more efficient cruiser produces lass fuel savings compared to the reference case.

3.2.4 Cruiser range variation

In these simulations the eight bases Transatlantic Scenario has been used. The cruiser X-Factor is 18500 nm and the Feeder X-Factor 14000 nm. As the feeder size variation has shown that the cruiser size has a main effect on the fuel savings in all simulation cases the first calculation has been done with optimal feeder bases.

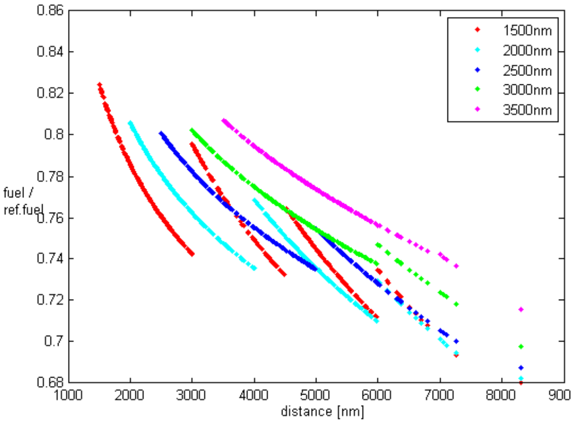

Figure 94 Fuel savings for singe cruiser routes and different cruiser design ranges.

Figure 9 shows the fuel savings for single cruiser routes by their distance. The calculations have been done with cruiser design ranges between 1500 nm and 3500 nm. The Cruiser gives their best performance over distances twice or three times their design range. None of the used Cruisers performs best at all distances. Also it could be seen that the 3000 nm cruiser and the 3500 nm cruiser never give the best results. The 2000 nm design range cruiser gives the best results for more distances than the other cruiser in the optimal bases case. Furthermore the less efficient points of each cruiser and the most efficient point of each cruiser form a U shaped curve. Cruiser with a design range of 2500 nm give the highest fuel saving results at their optimal distance and one refueling operation.

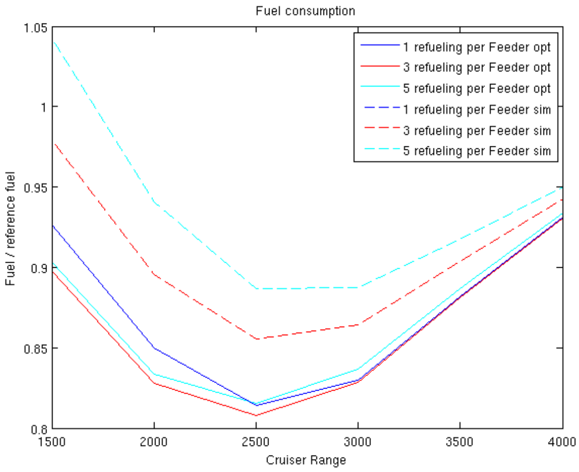

Figure 105 Fuel savings with different cruiser design ranges.

Figuer 10 shows the results in fuel saving in the simulation with optimal and simulated feeders. The feeders vary between one, three and five refueling operations per feeder. All 5 curves are U shaped and show the highest result in fuel saving for the 2500 nm cruiser. Cruiser with 2000 nm and 3000 nm still give could results with optimal feeder. In case of simulated feeders the difference between the optimal feeder case grows with lower cruiser design range. Thus the 3000 nm cruiser gives similar results as the 2500 nm cruiser in the simulation while the 2000 nm cruiser gives much less fuel savings. The distance between the curves for different feeder sizes grows as well for lower cruiser design ranges.

As the feeder bases have been selected for cruisers with 2500nm and 3000 nm it is not surprising that theses cruisers give the best results. But as the results with optimal bases show a similar curve it could be assumed that only a part of the losses in fuel savings for other cruiser ranges come from suboptimal feeder bases.

With the cruiser design range the cruiser mass also varies. With the number of cruiser and the number of feeder in the simulation the mass flying in the complete system could be calculated as well as the mass in the reference system without air to air refueling.

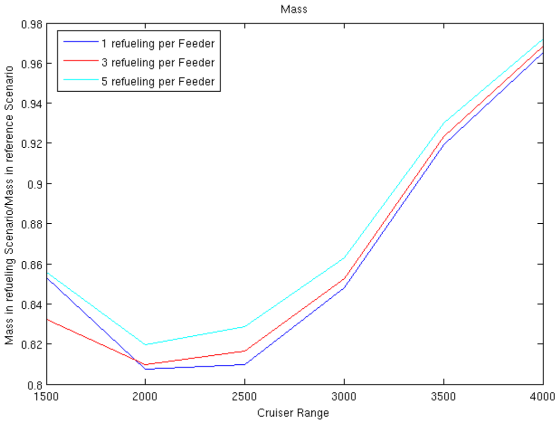

Figure 116 System mass with different cruiser design ranges.

Figure 11 shows the system mass over different cruiser design range and for feeder of different sizes. The results have been calculated with the full simulation as the calculation with optimal feeder does not give a necessary feeder number. As expected the system mass grows with the cruiser mass at higher cruiser design range. Between 2000 nm and 2500 nm the number of feeders graduates the rise in cruiser mass. Thus the 2000nm cruiser and the 2500 nm cruiser produce a similar system mass with feeder for one refueling operation. The 1500 nm cruiser makes enough feeders necessary to produce more mass than the lower design ranges saves. Particularly feeders for one refueling operation make a high number of feeders necessary.

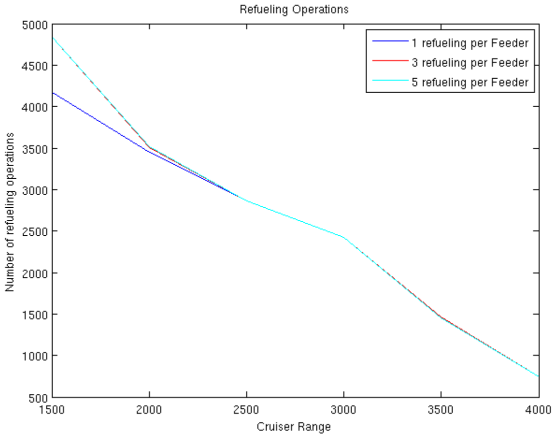

Figure 127 Number of refueling operations per cruiser with different cruiser design ranges.

The number of refueling operations per Cruiser rises to nearly two refueling operations for cruiser with a 15000 nm design range. Figure 11 shows also that no route in the scenario requires more than one refueling operation when flown with a 4000 nm Cruiser.

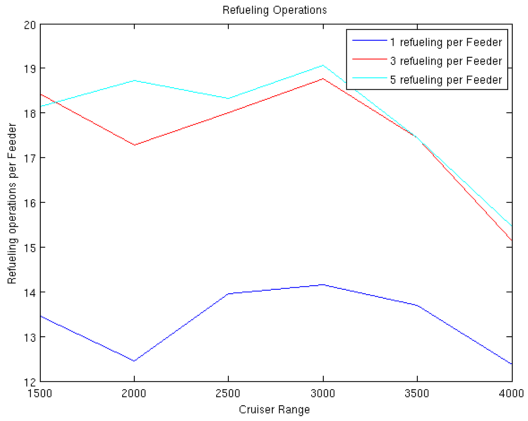

Figure 138 Number of refueling operations per feeder with different cruiser design ranges.

The number of refueling operations per Feeder over the 48 hours period in the simulation mainly depends on the number of refueling operations each feeder could perform on one mission. On the other hand with higher cruiser ranges the number decreases. The lower refueling operations in the system make it harder to keep huger feeder occupied and thus the number of refueling operations per feeder over the day decreases.

3.2.5 Feeder range variation

As mentioned in the feeder size variation the allowed area for refueling operations around the feeder base could also be varied. Feeder huge enough for more refueling operation should be scheduled easier when remaining in a smaller area. The Simulation uses again the eight bases Transatlantic Scenario. The Cruiser has a design range of 3000 nm and an X-Factor of 18500. The Feeder X-Factor is 14000 nm.

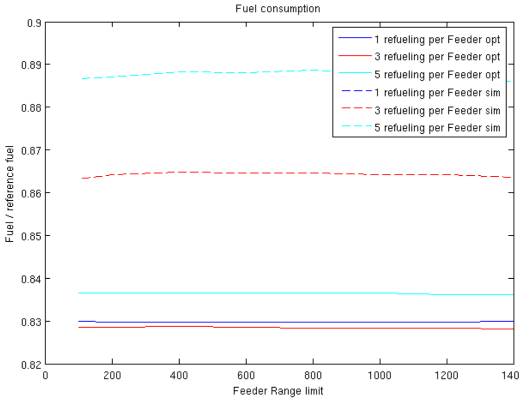

Figure 149 Fuel savings with different feeder Range limits

Figure 14 shows the fuels savings with different Range limits around the feeder base. It could be seen that the Range limit has only very little effect on the fuel savings in the complete system. As the routes are fuel optimized Feeder simply do not use these high distances. Their use would mean to sacrifice fuel for a refueling operation which is very inefficient. Small Feeder could not even reach the allowed distance. Thus the few connections where the use of high distances actually gives a benefit in fuel are very rare. Thus the rage limitation has only a very little effect on the fuel savings in the complete system.

The following Figure 15 shows the number of refueling operations in the system with different feeder range limits. Longer allowed distances do not result in more refueling operation. This shows that the allowed range is not used. Range limitations lower than 600 nm result in a rise of refueling operations per feeder. For some connections routes with one refueling operation are no longer possible with these range limitation. Thus they switch to routes with two refueling operations and cause a rise in refueling operations in the complete system. On the other hand at 2423 refueling operation in the system additional 25 refueling operations have a very low effect on the system performance.

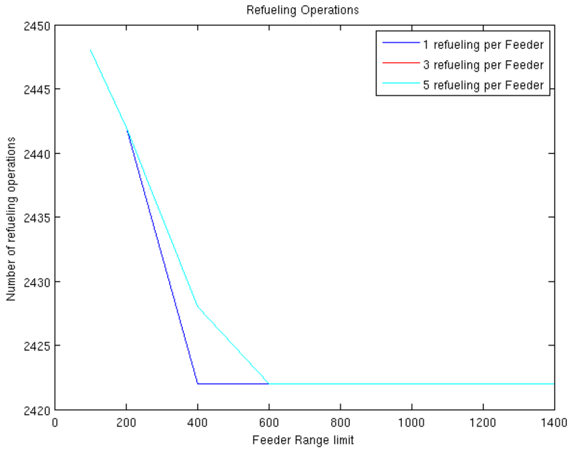

Figure 1510 Number of refueling operations with different feeder Range limits

3.2.6 Heavier and less efficient Cruiser

Further studies within the recreate project on possible cruiser designs indicate that it will not be possible to build a short range aircraft with the same efficiency as a long range aircraft if both aircrafts are designed with the same technology level. Also it could be shown that the first estimation for the cruiser weight was too low.
Thus the simulation parameters have been adjusted to simulate the air to air refueling network with less efficient (X=17500nm) and slightly heavier cruisers while the reference aircraft keeps its high efficiency (X = 18500 nm).

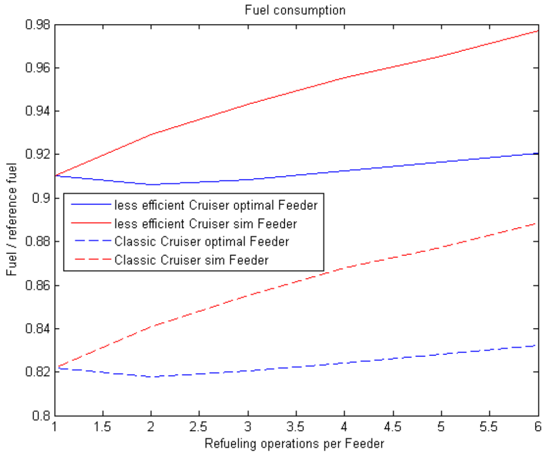

Figure 1611 Fuel savings with different Feeder sizes in the Transatlantic Scenario of the Classic Cruiser and a heavier less efficient Cruiser

Figure 16 shows the fuel savings in the whole traffic system with the less efficient cruiser and the classic cruiser. Different feeder sizes have been used in the simulation with simulated as well as optimal feeder scheduling. It could be seen that the system behaves in the same way but with much less fuel savings than with the classic cruiser. Even though the savings are much lower the use of the less efficient cruiser does only result in a minor decrease of connections with air to air refueling.

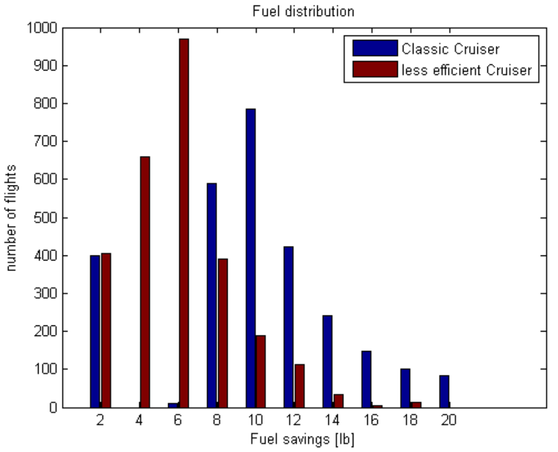

Figure 17 Distribution of fuel savings per flight in thousand lb for the classic cruiser and the less efficient cruiser !!!! graphic korrigieren

Figure 17 shows a small gap between the cruiser without refueling operations and the majority of cruiser with air to air refueling in the refueling system with the classic cruiser configuration. This gap closes in simulations with the less efficient cruiser. The majority of flights with the less efficient cruiser save only between 2000 and 8000 lb of fuel (classic cruiser: 8000-14000 lb). Thus further reduction in efficiency would lead to a significant reduction of flight with reasonable air to air refueling.

4 Conclusions

Even in a complete traffic scenario with a wide variation of connections the concept of air to air refueling could be used to save around 10% of fuel. As the fuel part of the overall aircraft weight growth with longer ranges the concept brings the best results on long range flights. Furthermore cruiser ranges between 2000 and 3000 nm seem most reasonable (Fig. 9) to replace connection of over 5000 nm.

Future growth in aircraft efficiency will lead to less fuel savings in this system. On the other hand the system will benefit from more efficient feeder and will still result in fuel savings on very long range connections.

The main savings result from weight reduction between long and short range aircrafts as long as the short range aircraft could keep up to the efficiency of the long range aircraft. Even with less efficient cruisers the system could still result in fuel savings of up to 10%.

Feeder for only one refueling operation are the most flexible solution and give the best results with simulated feeders while highly optimized feeder routes give the best results with feeders for 2 and 3 refueling operation. Optimizing the cruiser schedules on the feeder might enable the system to close on these results.

5 References

[1] NANGIA, R.K., " Operations and Aircraft Design towards ‘Greener’ Civil Aviation using Air-to-Air Refuelling ", RAeS Aeronautical Journal, Volume 110, No. 1113, pp 705-721, November 2006.

[2] NANGIA, R.K. “Highly Efficient and Greener Civil Aviation – Organising a Step Jump towards ACARE Goals An Opportunity for the Present & a Vision for Future” RAeS Conference “Aerospace 2008, The Way Forward”, London, 22-24 April 2008

[3] Toydas, Murat, “Fuel Saving Opportunities from Air Refueling”, Thesis (AFIT-LSCM-ENS-10-12), Department of the Air Force Air University, Air Force Institute of Technology, March 2010

[4] Bennington, M.A., Visser, K. D., "Aerial Refuelling Implications for Commercial Aviation" Journal of Aircraft, 2005, Vol. 42, No.2

[5] Eurocontrol Traffic from 1.7.2011

Copyright Statement