AN HEURISTIC APPROACH FOR LARGE SCALE CREW SCHEDULING PROBLEMS AT RIO-SUL AIRLINES

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Abstract – The airline crew scheduling problem entails the assignment of planned rotations to the airline crew members. This paper presents a real research conducted in Rio-Sul Airlines to solve real schedules. An heuristic approach is presented using the Bin-Packing problem solving techniques, guided by mathematical models which consists in two procedures: the first one tries to guarantee that all the planned assignments are done, always obeying the federal and crew member regulations; a second step carries out successive improvements of the original schedule, in order to reach a fair duty distribution. Schedules obtained and computational results are also presented.

Keywords: Crew Scheduling, Bin-Packing, Heuristic, Integer Programming

1.0 - INTRODUCTION

Crew costs in air transportation are extremely high, amounting up to 20% of total airlines operation costs. Therefore, airlines consider that efficient management of their crew staff is a question of highest economic relevance. Unfortunately, the numerical solutions of the associated large scale and combinatorial optimization problems are very difficult to obtain.

Following the development of Computer Science, many optimization approaches have been proposed to solve this problem: first mathematical programming methods (Mixed Linear and Integer Programming) and more recently artificial intelligence methods (logical programming, constraint programming) as well heuristic approaches and their respective combinations.

Several approaches for the crew scheduling problem have been presented in the literature. Important heuristics include simulated annealing [4] [8] and genetic algorithms [7]. Exact approaches include tree search, dynamic programming, column generation and branch and cut [2], [3], [5], [6]. A new formulation and its decomposition algorithm is presented in [10]. An interesting article that describes the crew scheduling problem is showed in [9].

This paper will describe an hybrid approach, using heuristic procedures combined to mathematical programming in different steps of the process, to solve real crew scheduling problems in Rio-Sul Airlines. The method apply sequential heuristics in which the general problem is decomposed and then solved by a mathematical model for each subset of crew members, reducing the combinatorial size of the entire problem.

The paper is organized as follows. Section 2 describes the problem of assigning pairings to crew members; section 3 presents a new mathematical model representing the problem; section 4 proposes an heuristic approach to solve large schedules. Computational results are presented in section 5 and some conclusions are presented in the last section.

2.0 – PROBLEM DESCRIPTION

The airline crew scheduling problem asks to assign crews to flights so as to serve all the operated flights and minimize crew costs. The problem is characterized by an overall objective function, which is composed of a couple of conflicting objectives as well by a set of complex constraints imposed by federal aviation regulations, union work rules, company polices, crew's working conditions and payment.

Traditionally, the crew scheduling problem is solved in a two steps process. At first, flights are grouped into duties (or rotations) named "pairings", and then those pairings must be assigned to the company available crew. In that way, some of the related constraints are guaranteed by generating pairings and some others must be considered at the assignment moment. Here are some of the most important Brazilian Aviation Regulations:

2.1 Aviation Regulation guaranteed during Pairing Generation

No crew member may fly more than 9 ½ hours per day;
The total work of a duty day cannot be higher than 12 hours;
Between two duty days must be assigned a rest period of 12 hours;
Each crew member must return to base in a maximum of 6 days ;
No crew member may land more than 5 times during one day;
Changing aircrafts must obey a fixed time established by each airport.

2.2 - Aviation Regulation guaranteed during Crew Scheduling

For all crew members must be assigned at least 6 days-off and 1 weekend day-off (48 hours, that must contain fully 24 hours on a Saturday or Sunday)
No crew member will work continuously more than 6 periods of 24 hours without receiving a day-off or a weekend day-off;
No crew member may be assigned to more than 2 alert duties on a week;
No crew member may be assigned to more than 8 alert duties on a month;

2.3 – Quality Criterias guaranteed during Crew Scheduling

The total kilometers to be flown must be distributed equally, in order to balance salary earnings;
The total time flown must be distributed equally, such as combined to balanced kilometers flown, can propitiate equal time of daily, night and week-end works;
A crew member might not be assigned to a day-off immediately after an alert duty day (this may cause problems in scheduling execution, if the crew member is set in motion during an alert time for a duty with more than one day);
There must be assigned to all crew members at least one flight rotation every week;
Previous solicitations by the crew members asking for days-off or rotations in specific dates, must be tried to be assigned preferentially;

3.0 – The Assignment Model

The problem consists to assign planned rotations and days-off to available crew members. So consider the set of crew members I and the set of all tasks *J*. The decision of assigning a task $j \in J$ to a crew member $i \in I$ is represented by x_{ij}, which can assumes value 1 if this assignment is done and value 0 otherwise. The main goal is to find a solution in which crew members, kilometers and time to be flown will be balanced.

Consider still the family set $\Omega = \{J_1 \cup J_2 \cup \cdots \cup J_k\}$, $\Omega \subseteq J$, where each J_s, $1 \leq s \leq k$, is a subset of the set of all tasks *J*, i.e., $J_s \subseteq J$, and all the tasks in J_s overlapping in time. There is another family set $\Psi = \{F_1 \cup F_2 \cup \cdots \cup F_w\}$, $\Psi \subset J$, where each F_r, $1 \leq r \leq w$, consists a set of possible days-off that can occurs between $D^r_{\min}$ and $D^r_{\max}$. The limits $D^r_{\min}$ and $D^r_{\max}$ define a time-window in which a crew member must receive one day-off. Each planned rotation requires a exact number of crew members, defined by n_j and have its length in kilometers expressed by m_j.

$$
\begin{cases}
Maximize\ \alpha z + \beta t \\
SubjectTo \\
\sum_{i \in I} x_{ij} = n_j & , \forall j \in J \quad (1) \\
\sum_{j \in J_s \subset \Omega} x_{ij} \le 1 & , \forall s, 1 \le s \le k, \forall i \in I \quad (2) \\
\sum_{j \in F_r \subset F} x_{ij} \ge 1 & , \forall r, 1 \le r \le w, \forall i \in I \quad (3) \\
\sum_{j \in F} x_{ij} \ge 8 & , \forall i \in I \quad (4) \\
z \le \sum_{j \in J} m_j x_{ij} & , \forall i \in I \quad (5) \\
t \le \sum_{j \in J} h_j x_{ij} & , \forall i \in I \quad (6) \\
x_{ij} \in \{0,1\} & , \forall i \in I, \forall j \in J \\
z \ge 0, t \ge 0
\end{cases}
$$

The problem formulation is described as follows:

The first constraint set expresses that each pairing must be covered exactly the desired number of times; the second constraint set represents the set of overlapping pairings in time that have to be assigned to different crew members. These relations can be found by searching in conflict graphs [1]; the third set of constraints is composed by time-windows that requires that each crew member will be assigned at least one day-off. Doing so, no crew member will work more than 6 days consecutively without receiving a day-off; the forth set of constraints ensure that all crew members receive at least 8 days-off.

The fifth set of constraints ensure that the variable maximized at the objective function will be less or equal the sum of kilometers flown by each crew member and the sixth constraint has the same behavior as the fifth, regarding to the time flown. In order to present a more generic model, only the major constraints of the problem were showed above.

The multi-objective function has two terms. A max-min function that increases the minimum time and kilometers flown by each crew member, pushing them together to the average values. In company regulation, rotations that happen on Sundays and during a certain period of the night (06:00 pm to 06:00 am), and its combinations, have different weights during payment calculation. When time and kilometers flown are balanced together, the system is doing more than balance crew earnings. In fact, balances the time worked on Sundays and during nights indirectly. In order to preserve the magnitude of values from kilometers and seconds, two constants $\alpha \ge 0$ and $\beta \ge 0$ are previously calculated, and they are based on the values of kilometers and seconds average from each problem considered.

This mathematical model was used and it was solved in reasonable time for small bases, involving up to 20.000 binary variables. However, there were problems higher than those ones, involving more than 700.000 binary variables (360 crew members to be assigned to 2000 rotations), which have demanded for further researches in order to establish other procedures to solve them.

4.0 – THE HEURISTIC APPROACH

Because most scheduling problems are large, it is difficult reach the global optimal solution. Most existing methods apply sequential heuristics in which the general problem is decomposed into several smaller ones that consider far fewer alternatives and can therefore be solved optimally.

Each method for decomposing the global problem has its own disadvantages. Schedules constructed pilot by pilot are not often uniform quality. The day-by-day method cannot take account of problems that may arise when scheduling for later days [11].

4.1 – Avoiding uncovered rotations

In this heuristic approach, the pilot-by-pilot decomposing was chosen to be performed. The technique used is similar to those related to the bin-packing problem and the pairing distribution is conducted trying to guarantee that the maximum set of tasks can be assigned.

The bin packing problem (BPP) is a well-known NP-hard grouping problem: items of various sizes have to be grouped inside bins of fixed capacity. Actually, the propose of initial assignment it's only similar to the BPP, because in the classical version, the objective is to minimize the number of bins used. In this assignment step, the bins (crew members) do not have the same capacity, and all of them must receive working duties. Because schedules are very tight, the main problem is to avoid uncovered pairings at the end of the process. The allocation pilot by pilot chooses a crew member (bin) and then uses a mathematical model to assign the most quantity of duty to him at each step.

In this matter, there are two main selection strategies: the first one is to select the convenient crew member to be assigned and the second one is to select the set of pairings to have the precedence to the current assignment phase.

The first strategy is natural, and crew members are chosen beginning with the ones who have more time of blocked days to the total schedule. It is easy to understand that those who have more impediments to receive the pairings have to be treated first. The algorithm let those who has the total time available to work to be the last ones.

A mathematical model controls the second strategy of selection. The objective function is composed by two terms: the duration of the pairing and by the evaluation of how critic is the task for the entire schedule. The first term is intuitive, once pairings longer in time duration (like larger objects) are more difficult to be assigned in the final steps. The second term of the function is obtained by a global analysis of the schedule and it is done as shown:

If we can imagine a line of time that goes through all the days of the related schedule, we would observe that there are moments in time that have more tasks occurring at the same time than others. Those peaks and valleys determine the critic value of each task and can be formally described as:

Definition. Each planned rotation $j \in J$ has a critical value $v_j = \underset{1 \le s \le k}{Max}\{|J_s| \mid j \in J_s\}$. It corresponds to the maximum overlapping in time with others planned rotations.

Each planned rotation has its duration in minutes expressed by d_j, and the maximum length in kilometers is denoted by *D*, i.e., $D = \underset{j \in J}{Max}\{d_j\}$. The model used to conduct this first step is:

$$
\begin{cases}
Maximize \ \sum_{i \in I} \sum_{j \in J} (Dv_j + d_j) x_{ij} \\
SubjectTo \\
\sum_{i \in I} x_{ij} \le n_j & , \forall j \in J & (1) \\
\sum_{j \in J_s \subset \Omega} x_{ij} \le 1 & , \forall s, 1 \le s \le k, \forall i \in I & (2) \\
\sum_{j \in F_r \subset F} x_{ij} \ge 1 & , \forall r, 1 \le r \le w, \forall i \in I & (3) \\
\sum_{j \in F} x_{ij} \ge 8 & , \forall i \in I & (4) \\
x_{ij} \in \{0,1\} & , \forall i \in I, \forall j \in J
\end{cases}
$$

4.2 – Searching for a Balanced Distribution

Unfortunately this approach produces a final unbalanced distribution. The crew members selected at the beginning of the process receives the maximum of possible time duty and the last ones receives less work, even no rotations can be assigned to them.

In order to get a balanced scheduling, some crew members are selected each time to promote a redistribution of tasks among them. This is reached by the use of the model that is presented in section 3. The success of this heuristic approach depends on the number and the characteristics of the crew members selected at each step. Here the model proposed is able to obtain the best redistribution among the crew members that had their previous scheduling deselected.

At each iteration of this procedure, the standard deviation of kilometers among all crew members is evaluated. If the goal is not reached yet, a certain number of crew member is selected and submitted to model. This procedure is repeated until the standard deviation of time and kilometers distribution or run time limit has been reached.

During first iterations, due to great unbalanced distribution of kilometers among the crew members selected, the standard deviation decreases rapidly but this characteristic reduces as long as the number of iterations increase.

4.0 – Computational Results

The problem data consists of manually constructed rotations by Rio-Sul Airlines planners, and refers to real working schedules for pilots (PN1 and PN2) and flight attendants (PN 3) from three different bases. The first one is a small base for 8 pilots and 93 rotations; the second is a medium base for 70 pilots and 300 rotations; the last one is the largest problem referring to 350 flight attendants and 2000 rotations to all four fleets (E-120, B735, FK50, E145), from the largest base.

Table 1 contains the results for three test problems. The columns #Crew and #Parings give the number of crew members and pairings, respectively. The column dimension describes them showing the number of variables versus the number of constraints. For the problem PN1, the solver reached a sub-optimal solution in 3 hours (node 2296 at the branch-and-bound tree) and it did not increase the value of objective for the next 48 hours.

All mathematical models were solved in a microcomputer Pentium III, 500 MHz, with 128 MB of RAM using XPRESS-MP v. 11. The stopping condition was a coefficient of variation equal or less than 5% to relative distribution of kilometers and flying hours among all crew members.

PN	#Crew	#Pairings	Dimension (nvarXnconst) x1000	Exact(1) (min)	Heuristic	
					Packing Phase(2) (min)	Refinement Phase(3) (min)
1	8	93	1,3 x 1,6	180	3	45
2	70	300	21 x 70	Not available	40	360
3	350	2000	700 x 1000	Not available	90	600

Table 1: Computational results

(1) Time spent to reach a sub-optimal solution corresponding to a gap of 4% from the bound of linear relaxation;
(2) Time spent to build a complete solution in the first phase of the heuristic process;
(3) Time spent to balance the kilometers and the seconds to be flown by each crew member with a coefficient of variation of 5% for both distributions.

In order to evaluate the performance of the proposed heuristic, a comparison was made between the exact and heuristic solutions found for the problem 1. The exact method built a schedule where the minimum total of kilometers flown was 45455 and the minimum total time flown was 63 hours and 43 minutes; heuristic solution reached the values 45890 and 63 hours and 43 minutes respectively. Applying the constants α = 0.51 and β = 0.1, the objective function for both methods were respectively 4553 and 4634. These objective function values show that the proposed heuristic procedure reached a better solution, which is closer to the bound of the linear relaxation of the problem, with a gap less than 2% from optimal solution, while the exact approach stayed 4% distant from the same value, but for a sub-optimal solution (the better solution found in 51 hours).

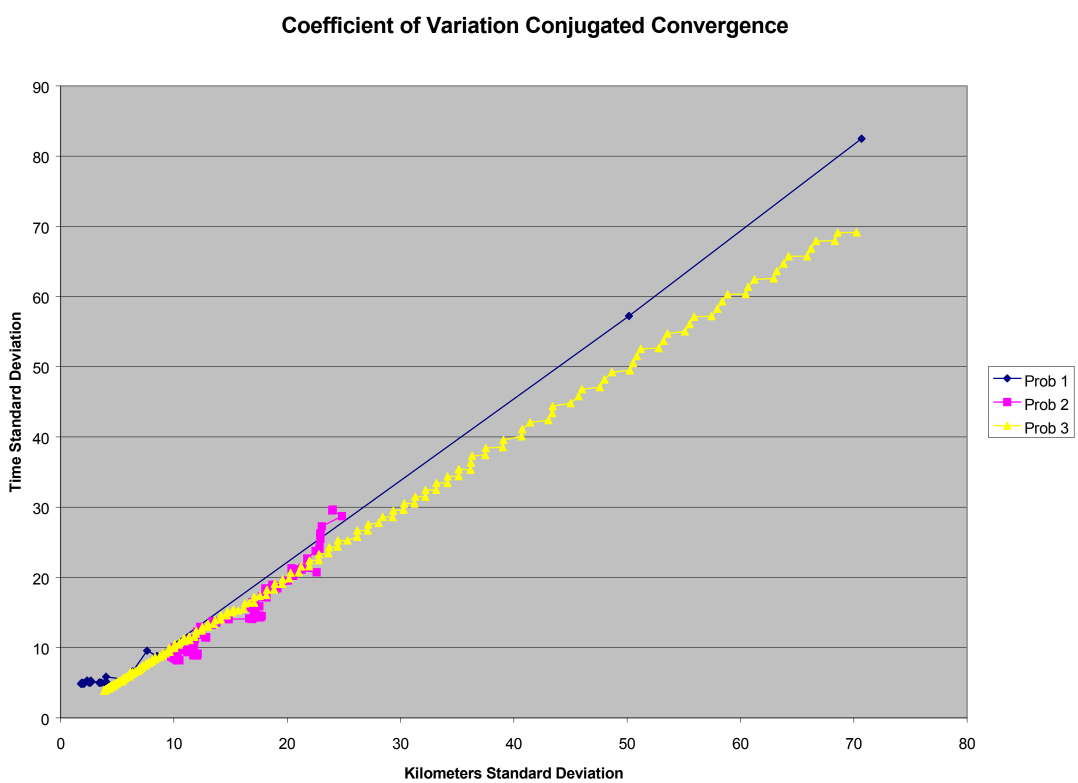

Fig nr 1 – Coefficient of Variation Conjugated Convergence

The graphic above shows the convergence of both standard deviation (time and kilometers) flown for the successive refinements. For larger problems (PN2 and PN3) we can see the heuristic guiding the successive choices of pilots to have the tasks to be changed among themselves. Some iterations bring crew members who are far form the average considering the time flown, and some others considering the kilometers flown; the result is a zigzag behavior for the descending curve.

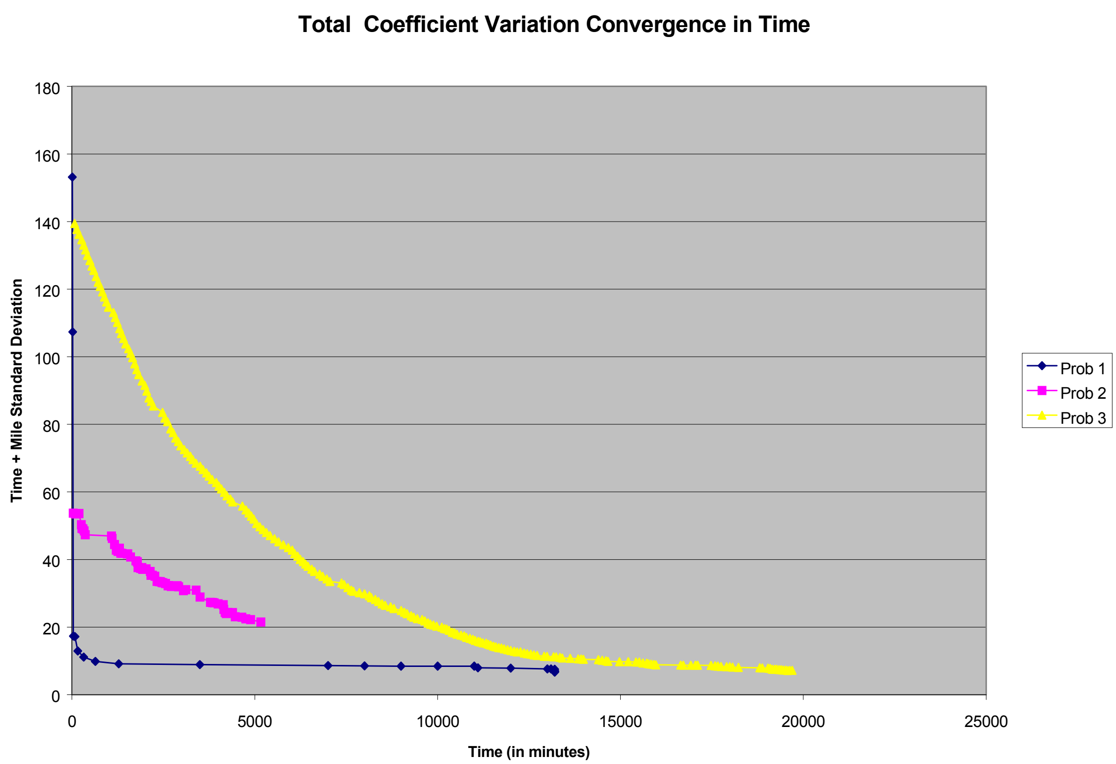

Fig nr 2 – Coefficient of Variation Convergence in Time

The graphic above shows the convergence of the objective function along the time. The smaller schedule (PN 1) presents a drastic decrease at the beginning of the process and then stays stable as the time goes on. The larger problems (PN2 and PN3) has a soft descend and can be understood as the result of the number of crew members selected to be refined at each step is very few regarded to the total of crew members that compose the entire schedule.

5.0 – Conclusions

The method described in this paper has been used to solve pilots and flight attendants' problems in Rio-Sul Airlines. The use of the hybrid approach that combines heuristics procedures with mathematical programming at the several steps of the process has generated good schedules in satisfactory time.

When schedules refers to small bases, the global optimality is reached by applying the model described in section 1 to all the crew members; for medium to large bases the constructive solution proposed has been used with great success.

As mentioned previously, the hybrid procedure proposed has reached solutions that are found to be within 10% off the bound of linear relaxation in small bases, where the two approaches (exact and heuristic) can be generated for both methods for comparison. These results can be projected to larger schedules and the same behavior can be expected.

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APPENDIX 1 - THE GENERATED SCHEDULES

KILOMETER AVERAGE (ARITHMETIC MEAN): 46229
HOURS FLOWN AVERAGE (ARITHMETIC MEAN): 65:33

EXACT SCHEDULE

KILOMETERS STD DEVIATION: 874,7463
KILOMETERS COEFFICIENT OF VARIATION: 1,892177 %
SECONDS STD DEVIATION: 7535,364
SECONDS COEFFICIENT OF VARIATION : 3,19312 %

TASK	BEGIN	END	FLIGHT TIME	KM FLOWN
PILOT NR: 1				
50149134	10/01/99 19:30	10/02/99 16:07	05:13	3452
50149135	10/02/99 19:30	10/03/99 16:07	05:13	3452
50149199	10/04/99 07:00	10/05/99 08:00	0	1960
DAY-OFF	10/05/99 16:00	10/06/99 16:00	0	0
50149139	10/06/99 19:30	10/07/99 16:07	05:13	3452
50149172	10/08/99 08:30	10/10/99 13:37	11:42	5240
DAY-OFF	10/10/99 13:37	10/11/99 13:37	0	0
50149207	10/12/99 07:00	10/13/99 08:00	0	1960
50149177	10/13/99 08:30	10/15/99 13:37	11:42	5240
DAY-OFF	10/15/99 16:00	10/16/99 16:00	0	0
50149212	10/17/99 07:00	10/18/99 08:00	0	3640
DAY-OFF	10/18/99 08:00	10/19/99 08:00	0	0
50149183	10/19/99 08:30	10/21/99 13:37	11:42	5240
DAY-OFF	10/21/99 16:00	10/22/99 16:00	0	0
WEEK-OFF	10/22/99 16:00	10/24/99 16:00	0	0
50149157	10/24/99 19:30	10/25/99 16:07	05:13	5374
50149190	10/26/99 08:30	10/28/99 13:37	11:42	5240
DAY-OFF	10/28/99 13:37	10/29/99 13:37	0	0
50149225	10/30/99 07:00	10/31/99 08:00	0	1960
		TOTALS:	67:40	46210
PILOT NR: 2				
DAY-OFF	10/02/99 08:00	10/03/99 08:00	0	0
50149136	10/03/99 19:30	10/04/99 16:07	05:13	5374
50149137	10/04/99 19:30	10/05/99 16:07	05:13	3452
50149201	10/06/99 07:00	10/07/99 08:00	0	1960
DAY-OFF	10/07/99 08:00	10/08/99 08:00	0	0
50149141	10/08/99 19:30	10/09/99 16:07	05:13	3452
WEEK-OFF	10/09/99 16:07	10/11/99 16:07	0	0
DAY-OFF	10/12/99 08:00	10/13/99 08:00	0	0
DAY-OFF	10/13/99 08:00	10/14/99 08:00	0	0
50149149	10/16/99 19:30	10/17/99 16:07	05:13	3452
50149151	10/18/99 19:30	10/19/99 16:07	05:13	3452
50149152	10/19/99 19:30	10/20/99 16:07	05:13	3452
50149153	10/20/99 19:30	10/21/99 16:07	05:13	3452
DAY-OFF	10/21/99 16:07	10/22/99 16:07	0	0
50149155	10/22/99 19:30	10/23/99 16:07	05:13	3452
50149219	10/24/99 7:00	10/25/99 8:00	0	3640
50149189	10/25/99 8:30	10/27/99 13:37	11:42	5240
DAY-OFF	10/27/99 13:37	10/28/99 13:37	0	0
50149193	10/29/99 8:30	10/31/99 13:37	11:42	5240
		TOTALS:	65:08	45618
PILOT NR: 3				
50149165	10/01/99 08:30	10/03/99 13:37	11:42	5240

DAY-OFF	10/03/99 16:00	10/04/99 16:00	0	0
50149169	10/05/99 08:30	10/07/99 13:37	11:42	5240
50149203	10/08/99 07:00	10/09/99 08:00	0	1960
DAY-OFF	10/09/99 16:00	10/10/99 16:00	0	0
50149143	10/10/99 19:30	10/11/99 16:07	05:13	5374
50149208	10/13/99 7:00	10/14/99 8:00	0	1960
DAY-OFF	10/14/99 16:00	10/14/99 16:00	0	0
50149148	10/15/99 19:30	10/16/99 16:07	05:13	3452
50149181	10/17/99 08:30	10/19/99 13:37	11:42	7869
50149215	10/20/99 07:00	10/21/99 08:00	0	1960
DAY-OFF	10/21/99 08:00	10/22/99 08:00	0	0
50149156	10/23/99 19:30	10/24/99 16:07	05:13	3452
DAY-OFF	10/25/99 08:00	10/26/99 08:00	0	0
DAY-OFF	10/26/99 08:00	10/27/99 08:00	0	0
50149191	10/27/99 08:30	10/29/99 13:37	11:42	5240
WEEK-OFF	10/29/99 16:00	10/31/99 16:00	0	0
50149164	10/31/99 19:30	11/01/99 16:07	05:13	5374
		TOTALS:	67:40	47121

PILOT NR: 4

50149198	10/03/99 07:00	10/04/99 08:00	0	3640
DAY-OFF	10/04/99 08:00	10/05/99 08:00	0	0
50149170	10/06/99 08:30	10/08/99 13:37	11:42	5240
DAY-OFF	10/08/99 16:00	10/08/99 16:00	0	0
50149142	10/09/99 19:30	10/10/99 16:07	05:13	3452
50149206	10/11/99 07:00	10/12/99 08:00	0	1960
DAY-OFF	10/12/99 16:00	10/13/99 16:00	0	0
50149146	10/13/99 19:30	10/14/99 16:07	05:13	3452
50149147	10/14/99 19:30	10/15/99 16:07	05:13	3452
50149180	10/16/99 08:30	10/18/99 13:37	11:42	6934
DAY-OFF	10/19/99 08:00	10/20/99 08:00	0	0
50149184	10/20/99 08:30	10/22/99 13:37	11:42	5240
50149218	10/23/99 07:00	10/24/99 08:00	0	1960
DAY-OFF	10/24/99 08:00	10/25/99 08:00	0	0
50149158	10/25/99 19:30	10/26/99 16:07	05:13	3452
50149159	10/26/99 19:30	10/27/99 16:07	05:13	3452
50149160	10/27/99 19:30	10/28/99 16:07	05:13	3452
DAY-OFF	10/28/99 16:00	10/29/99 16:00	0	0
WEEK-OFF	10/29/99 16:00	10/31/99 16:00	0	0
		TOTALS:	66:24	45686

PILOT NR: 5

50149196	10/01/99 07:00	10/02/99 08:00	0	1960
50149167	10/03/99 08:30	10/05/99 13:37	11:42	7869
DAY-OFF	10/05/99 16:00	10/06/99 16:00	0	0
DAY-OFF	10/06/99 16:00	10/07/99 16:00	0	0
50149140	10/07/99 19:30	10/08/99 16:07	05:13	3452
WEEK-OFF	10/09/99 08:00	10/11/99 08:00	0	0
50149175	10/11/99 08:30	10/13/99 13:37	11:42	5240
50149178	10/14/99 8:30	10/16/99 13:37	11:42	5240
DAY-OFF	10/16/99 16:00	10/17/99 16:00	0	0
50149150	10/17/99 19:30	10/18/99 16:07	05:13	5374
DAY-OFF	10/18/99 16:07	10/19/99 16:07	0	0
DAY-OFF	10/19/99 16:07	10/20/99 16:07	0	0
50149216	10/21/99 7:00	10/22/99 8:00	0	1960
50149186	10/22/99 8:30	10/24/99 13:37	11:42	5240
DAY-OFF	10/24/99 13:37	10/25/99 13:37	0	0
50149221	10/26/99 7:00	10/27/99 8:00	0	1960
50149161	10/28/99 19:30	10/29/99 16:07	05:13	3452
DAY-OFF	10/29/99 16:07	10/30/99 16:07	0	0
50149163	10/30/99 19:30	10/31/99 16:07	05:13	3452
		TOTALS:	67:40	45199

PILOT NR: 6

50149197	10/02/99 07:00	10/03/99 08:00	0	1960
DAY-OFF	10/05/99 08:00	10/06/99 08:00	0	0
50149168	10/04/99 08:30	10/06/99 13:37	11:42	5240
DAY-OFF	10/06/99 16:07	10/07/99 16:07	0	0
DAY-OFF	10/07/99 16:07	10/08/99 16:07	0	0
50149204	10/09/99 07:00	10/10/99 08:00	0	1960
50149174	10/10/99 08:30	10/12/99 13:37	11:42	7869
50149145	10/12/99 19:30	10/13/99 16:07	05:13	3452
DAY-OFF	10/13/99 16:07	10/14/99 16:07	0	0
50149210	10/15/99 7:00	10/16/99 8:00	0	1960
WEEK-OFF	10/16/99 16:07	10/18/99 16:07	0	0
50149182	10/18/99 8:30	10/20/99 13:37	11:42	5240
DAY-OFF	10/20/99 16:07	10/21/99 16:07	0	0
50149217	10/22/99 7:00	10/23/99 8:00	0	1960
50149187	10/23/99 8:30	10/25/99 13:37	11:42	6934
DAY-OFF	10/25/99 16:07	10/26/99 16:07	0	0
50149222	10/27/99 7:00	10/28/99 8:00	0	1960
50149224	10/29/99 7:00	10/30/99 8:00	0	1960
50149194	10/30/99 8:30	11/01/99 13:37	11:42	6934
		TOTALS:	63:43	47429

PILOT NR: 7

50149166	10/02/99 08:30	10/04/99 13:37	11:42	6934
50149200	10/05/99 07:00	10/06/99 08:00	0	1960
DAY-OFF	10/06/99 08:00	10/07/99 08:00	0	0
50149171	10/07/99 08:30	10/09/99 13:37	11:42	5240
50149205	10/10/99 07:00	10/11/99 08:00	0	3640
DAY-OFF	10/11/99 08:00	10/12/99 08:00	0	0
50149176	10/12/99 08:30	10/14/99 13:37	11:42	5240
DAY-OFF	10/14/99 16:00	10/15/99 16:00	0	0
50149211	10/16/99 07:00	10/17/99 08:00	0	1960
50149213	10/18/99 07:00	10/19/99 08:00	0	1960
DAY-OFF	10/19/99 08:00	10/20/99 08:00	0	0
DAY-OFF	10/20/99 08:00	10/21/99 08:00	0	0
50149154	10/21/99 19:30	10/22/99 16:07	05:13	3452
WEEK-OFF	10/22/99 16:07	10/24/99 16:07	0	0
50149220	10/25/99 07:00	10/26/99 08:00	0	1960
DAY-OFF	10/27/99 08:00	10/28/99 08:00	0	0
50149192	10/28/99 08:30	10/30/99 13:37	11:42	5240
50149195	10/31/99 08:30	11/02/99 13:37	11:42	7869
		TOTALS:	63:43	45455

PILOT NR: 8

WEEK-OFF	10/02/99 08:00	10/04/99 08:00	0	0
DAY-OFF	10/06/99 08:00	10/06/99 08:00	0	0
50149138	10/05/99 19:30	10/06/99 16:07	05:13	3452
50149202	10/07/99 07:00	10/08/99 08:00	0	1960
DAY-OFF	10/08/99 08:00	10/09/99 08:00	0	0
50149173	10/09/99 08:30	10/11/99 13:37	11:42	6934
50149144	10/11/99 19:30	10/12/99 16:07	05:13	3452
DAY-OFF	10/12/99 16:07	10/13/99 16:07	0	0
50149209	10/14/99 07:00	10/15/99 08:00	0	1960
50149179	10/15/99 08:30	10/17/99 13:37	11:42	5240
DAY-OFF	10/17/99 16:00	10/18/99 16:00	0	0
50149214	10/19/99 07:00	10/20/99 08:00	0	1960
DAY-OFF	10/20/99 08:00	10/21/99 08:00	0	0
50149185	10/21/99 08:30	10/23/99 13:37	11:42	5240
50149188	10/24/99 08:30	10/26/99 13:37	11:42	7869
DAY-OFF	10/26/99 13:37	10/27/99 13:37	0	0
50149223	10/28/99 07:00	10/29/99 08:00	0	1960
50149162	10/29/99 19:30	10/30/99 16:07	05:13	3452
50149226	10/31/99 07:00	11/01/99 08:00	0	3640
		TOTALS:	62:27	47119

HEURISTIC SCHEDULE

KILOMETERS STD DEVIATION:	410,365
KILOMETERS COEFFICIENT OF VARIATION:	0,8877%
SECONDS STD DEVIATION:	5684,545
SECONDS COEFFICIENT OF VARIATION:	2,408833 %

TASK	**BEGIN**	**END**	**FLIGHT TIME**	**KM FLOWN**
PILOT NR: 1				
50149135	10/02/99 19:30	10/03/99 16:07	05:13	3452
DAY-OFF	10/03/99 16:07	10/04/99 16:07	0	0
50149138	10/06/99 19:30	10/07/99 16:07	05:13	3452
DAY-OFF	10/03/99 16:07	10/04/99 16:07	0	0
50149172	10/08/99 08:30	10/10/99 13:37	11:42	5240
50149143	10/10/99 19:30	10/11/99 16:07	05:13	5374
DAY-OFF	10/11/99 16:07	10/12/99 16:07	0	0
50149208	10/13/99 7:00	10/14/99 8:00	0	1960
DAY-OFF	10/15/99 13:37	10/16/99 13:37	0	0
WEEK-OFF	10/16/99 13:37	10/18/99 13:37	0	0
DAY-OFF	10/19/99 0800	10/20/99 08:00	0	0
0149184	10/20/99 08:30	10/22/99 13:37	11:42	5240
50149155	10/22/99 19:30	10/23/99 16:07	05:13	3452
DAY-OFF	10/23/99 16:07	10/24/99 16:07	0	0
50149157	10/24/99 19:30	10/25/99 16:07	05:13	5374
50149221	10/26/99 07:00	10/27/99 08:00	0	1960
DAY-OFF	10/27/99 13:37	10/28/99 13:37	0	0
50149193	10/29/99 08:30	10/31/99 13:37	11:42	5240
50149164	10/31/99 19:30	11/01/99 16:07	05:13	5374
		TOTALS:	66:24	46118
PILOT NR: 2				
50149197	10/02/99 07:00	10/03/99 08:00	0	1960
DAY-OFF	10/03/99 08:00	10/04/99 08:00	0	0
50149168	10/04/99 08:30	10/06/99 13:37	11:42	5240
50149139	10/06/99 19:30	10/07/99 16:07	05:13	3452
50149203	10/08/99 07:00	10/09/99 08:00	0	1960
WEEK-OFF	10/09/99 08:00	10/11/99 08:00	0	0
DAY-OFF	10/11/99 08:00	10/12/99 08:00	0	0
50149176	10/12/99 08:30	10/14/99 13:37	11:42	5240
DAY-OFF	10/14/99 13:37	10/15/99 13:37	0	0
50149211	10/16/99 07:00	10/17/99 08:00	0	1960
50149181	10/17/99 08:30	10/19/99 13:37	11:42	7869
DAY-OFF	10/21/99 08:00	10/22/99 08:00	0	0
50149219	10/24/99 07:00	10/25/99 08:00	0	3640
DAY-OFF	10/25/99 08:00	10/26/99 08:00	0	0
50149190	10/26/99 08:30	10/28/99 13:37	11:42	5240
DAY-OFF	10/28/99 13:37	10/2999 13:37	0	0
50149225	10/30/99 07:00	10/31/99 08:00	0	1960
50149195	10/31/99 08:30	11/02/99 13:37	11:42	7869
		TOTALS:	63:43	46390
PILOT NR: 3				
50149165	10/01/99 08:30	10/03/99 13:37	11:42	5240
DAY-OFF	10/03/99 16:07	10/04/99 16:07	0	0
50149137	10/04/99 19:30	10/05/99 16:07	05:13	3452
50149201	10/06/99 07:00	10/07/99 08:00	0	1960
50149140	10/07/99 19:30	10/08/99 16:07	05:13	3452
50149204	10/09/99 07:00	10/10/99 08:00	0	1960
DAY-OFF	10/10/99 08:00	10/11/99 08:00	0	0
50149144	10/11/99 19:30	10/12/99 16:07	05:13	3452
50149145	10/12/99 19:30	10/13/99 16:07	05:13	3452
DAY-OFF	10/14/99 08:00	10/15/99 08:00	0	0
DAY-OFF	10/15/99 08:00	10/16/99 08:00	0	0

50149180	10/16/99 08:30	10/18/99 13:37	11:42	6934
50149151	10/18/99 19:30	10/19/99 16:07	05:13	3452
50149215	10/20/99 07:00	10/21/99 08:00	0	1960
DAY-OFF	10/21/99 08:00	10/22/99		
08:00	0		0	
50149186	10/22/99 08:30	10/24/99 13:37	11:42	5240
50149220	10/25/99 07:00	10/26/99 08:00	0	1960
DAY-OFF	10/26/99 08:00	10/27/99 08:00	0	0
50149160	10/27/99 19:30	10/28/99 16:07	05:13	3452
WEEK-OFF	10/29/99 16:00	10/31/99 16:00	0	0
		TOTALS:	66:24	45966

PILOT NR: 4

DAY-OFF	10/02/99 08:00	10/03/99 08:00	0	0
50149167	10/03/99 08:30	10/05/99 13:37	11:42	7869
50149170	10/06/99 08:30	10/08/99 13:37	11:42	5240
DAY-OFF	10/08/99 13:37	10/09/99 13:37	0	0
50149205	10/10/99 07:00	10/11/99 08:00	0	3640
50149175	10/11/99 08:30	10/13/99 13:37	11:42	5240
DAY-OFF	10/13/99 13:37	10/14/99 13:37	0	0
50149147	10/14/99 19:30	10/15/99 16:07	05:13	3452
DAY-OFF	10/15/99 16:07	10/16/99 16:07	0	0
50149212	10/17/99 07:00	10/18/99 08:00	0	3640
50149182	10/18/99 08:30	10/20/99 13:37	11:42	5240
50149216	10/21/99 07:00	10/22/99 08:00	0	1960
DAY-OFF	10/22/99 08:00	10/23/99 08:00	0	0
WEEK-OFF	10/23/99 08:00	10/25/99 08:00	0	0
DAY-OFF	10/25/99 13:30	10/26/99 13:30	0	0
50149222	10/27/99 07:00	10/28/99 08:00	0	1960
50149192	10/28/99 08:30	10/30/99 13:37	11:42	5240
50149226	10/31/99 07:00	11/01/99 08:00	0	3640
		TOTALS:	63:43	47121

PILOT NR: 5

50149134	10/01/99 19:30	10/02/99 16:07	05:13	3452
50149198	10/03/99 07:00	10/04/99 08:00	0	3640
DAY-OFF	10/04/99 08:00	10/05/99 08:00	0	0
50149169	10/05/99 08:30	10/07/99 13:37	11:42	5240
DAY-OFF	10/07/99 16:00	10/08/99 16:00	0	0
WEEK-OFF	10/08/99 16:00	10/10/99 16:00	0	0
50149206	10/11/99 07:00	10/12/99 08:00	0	1960
DAY-OFF	10/12/99 16:00	10/13/99 16:00	0	0
50149209	10/14/99 7:00	10/15/99 8:00	0	1960
50149179	10/15/99 8:30	10/17/99 13:37	11:42	5240
DAY-OFF	10/19/99 08:00	10/20/99 08:00	0	0
50149185	10/21/99 8:30	10/23/99 13:37	11:42	5240
50149156	10/23/99 19:30	10/24/99 16:07	05:13	3452
DAY-OFF	10/24/99 16:07	10/25/99 16:07	0	0
50149158	10/25/99 19:30	10/26/99 16:07	05:13	3452
50149159	10/26/99 19:30	10/27/99 16:07	05:13	3452
DAY-OFF	10/27/99 16:07	10/28/99 16:07	0	0
50149224	10/29/99 7:00	10/30/99 8:00	0	1960
50149194	10/30/99 8:30	11/01/99 13:37	11:42	6934
		TOTALS:	67:40	45982

PILOT NR: 6

50149196	10/01/99 07:00	10/02/99 08:00	0	1960
50149166	10/02/99 08:30	10/04/99 13:37	11:42	6934
DAY-OFF	10/05/99 08:00	10/06/99 08:00	0	0
DAY-OFF	10/06/99 08:00	10/07/99 08:00	0	0
50149171	10/07/99 08:30	10/09/99 13:37	11:42	5240
50149174	10/10/99 08:30	10/12/99 13:37	11:42	7869
DAY-OFF	10/12/99 16:00	10/13/99 16:00	0	0
50149146	10/13/99 19:30	10/14/99 16:07	05:13	3452

50149210	10/15/99 07:00	10/16/99 08:00	0	1960
DAY-OFF	10/16/99 13:30	10/17/99 13:30	0	0
50149213	10/18/99 07:00	10/19/99 08:00	0	1960
50149183	10/19/99 08:30	10/21/99 13:37	11:42	5240
DAY-OFF	10/21/99 13:37	10/22/99 13:37	0	0
50149218	10/23/99 07:00	10/24/99 08:00	0	1960
50149188	10/24/99 08:30	10/26/99 13:37	11:42	7869
DAY-OFF	10/26/99 16:00	10/27/99 16:00	0	0
50149223	10/28/99 07:00	10/29/99 08:00	0	1960
WEEK-OFF	10/29/99 08:00	10/31/99 08:00	0	0
		TOTALS:	63:43	46404

PILOT NR: 7

DAY-OFF	10/02/99 08:00	10/03/99 08:00	0	0
50149199	10/04/99 07:00	10/05/99 08:00	0	1960
DAY-OFF	10/05/99 13:00	10/06/99 13:00	0	0
50149202	10/07/99 07:00	10/08/99 08:00	0	1960
DAY-OFF	10/08/99 08:00	10/09/99 08:00	0	0
50149173	10/09/99 08:30	10/11/99 13:37	11:42	6934
DAY-OFF	10/11/99 16:00	10/12/99 16:00	0	0
50149177	10/13/99 8:30	10/15/99 13:37	11:42	5240
50149148	10/15/99 19:30	10/16/99 16:07	05:13	3452
50149149	10/16/99 19:30	10/17/99 16:07	05:13	3452
DAY-OFF	10/17/99 16:07	10/18/99 16:07	0	0
50149214	10/19/99 7:00	10/20/99 8:00	0	1960
50149153	10/20/99 19:30	10/21/99 16:07	05:13	3452
50149217	10/22/99 7:00	10/23/99 8:00	0	1960
DAY-OFF	10/23/99 08:00	10/24/99 08:00	0	0
WEEK-OFF	10/24/99 08:00	10/26/99 08:00	0	0
50149189	10/25/99 8:30	10/27/99 13:37	11:42	5240
DAY-OFF	10/27/99 13:37	10/29/99 13:37	0	0
50149161	10/28/99 19:30	10/29/99 16:07	05:13	3452
50149162	10/29/99 19:30	10/30/99 16:07	05:13	3452
50149163	10/30/99 19:30	10/31/99 16:07	05:13	3452
		TOTALS:	66:24	45966

PILOT NR: 8

50149136	10/03/99 19:30	10/04/99 16:07	05:13	5374
50149200	10/05/99 07:00	10/06/99 08:00	0	1960
DAY-OFF	10/06/99 08:00	10/07/99 08:00	0	0
50149141	10/08/99 19:30	10/09/99 16:07	05:13	3452
50149142	10/09/99 19:30	10/10/99 16:07	05:13	3452
DAY-OFF	10/10/99 16:07	10/11/99 16:07	0	0
50149207	10/12/99 07:00	10/13/99 8:00	0	1960
DAY-OFF	10/13/99 08:00	10/14/99 08:00	0	0
50149178	10/14/99 8:30	10/16/99 13:37	11:42	5240
DAY-OFF	10/16/99 16:00	10/17/99 16:00	0	0
50149150	10/17/99 19:30	10/18/99 16:07	05:13	5374
50149152	10/19/99 19:30	10/20/99 16:07	05:13	3452
DAY-OFF	10/20/99 16:07	10/21/99 16:07	0	0
50149154	10/21/99 19:30	10/22/99 16:07	05:13	3452
50149187	10/23/99 8:30	10/25/99 13:37	11:42	6934
DAY-OFF	10/25/99 16:00	10/26/99 16:00	0	0
50149191	10/27/99 8:30	10/29/99 13:37	11:42	5240
DAY-OFF	10/29/99 16:00	10/31/99 16:00	0	0
		TOTALS:	66:24	45890