An alternative MIP formulation for the Military Flight and Maintenance Planning problem

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1 Introduction

The Military Flight and Maintenance Planning (MFMP) Problem assigns missions and schedules maintenance operations (checks) for military aircraft. It has been studied in short, medium and long-term planning horizons ([1, 2, 5, 4]) and it has been proved NP-Hard in its long-term variant by [3]. The present model is an alternative formulation to that of [3] where mission assignments and maintenance cycles are modeled as start-stop assignment.

The problem consists in assigning aircraft $i \in \mathcal{I}$ to a set $j \in \mathcal{J}$ of missions while scheduling checks over a time horizon divided into $t \in \mathcal{T}$ periods. Missions have known start and end dates and require R_j aircraft to fly $H'_{jtt'}$ hours when assigned to mission j between periods t and t'. Each aircraft i can be assigned to only missions $j \in \mathcal{J}_i$ and is assumed to fly $U'_{tt'}$ hours between periods t and t' if not undergoing a check or a mission. Each period t has $j \in \mathcal{J}_t$ active missions.

Each aircraft i needs a check after H^{max} flight hours or less and has Rft_i^{Init} remaining flight hours at the beginning of the planning horizon. Only two checks can be assigned in the planing horizon: the first check is assigned during periods $t \in \mathcal{T}_i^{M_{Init}}$ and, a second check can be assigned during periods $t \in \mathcal{T}_t^{M+}$, if the first check was done in t. $\mathcal{T}_t$ is the set of check patterns that make an aircraft be in maintenance in period t; $\mathcal{J}_{jt}$ is the set of mission patterns that make aircraft be in mission j in period t; $\mathcal{J}_{itt'}$ is the set of mission patterns for aircraft i between periods t and t'.

2 Mathematical model

The following variables are defined in this new Integer Linear Formulation (ILP):

$a_{ijtt'}$ = 1 if aircraft i starts mission j at period t and finishes at period t', 0 otherwise.

$m_{itt'}$ = 1 if aircraft i starts a check at period t and then starts the next check at period t', 0 otherwise.

The objective is to delay the second check as much as possible.

$$\text{Max} \sum_{i\in\mathcal{I},t\in\mathcal{T}_i^{M_{Init}},t'\in\mathcal{T}_t^{M+}} m_{itt'} \times t' \tag{1}$$

$$\sum_{i\in\mathcal{I},(t_1,t_2)\in\mathcal{T}_t} m_{it_1t_2} \leq C^{max} \qquad t \in \mathcal{T} \tag{2}$$

$$\sum_{i\in\mathcal{I}_j,(t_1,t_2)\in\mathcal{T}_{jt}} a_{ijt_1t_2} \geq R_j \qquad j \in \mathcal{J}, t \in \mathcal{T}\mathcal{J}_j \tag{3}$$

$$\sum_{(t_1,t_2)\in\mathcal{T}_t} m_{it_1t_2} + \sum_{j\in\mathcal{J}_t\cap\mathcal{J}_i} \sum_{(t_1,t_2)\in\mathcal{T}_{jt}} a_{ijt_1t_2} \leq 1 \qquad t \in \mathcal{T}, i \in \mathcal{I} \tag{4}$$

$$\sum_{(j,t,t')\in\mathcal{J}_{i1t_1}} a_{ijtt'}H'_{jtt'} + U'_{1t_1} \leq Rft_i^{Init} + H^{max}(1 - m_{it_1t_2}) \qquad i \in \mathcal{I}, t_1 \in \mathcal{T}_i^{M_{Init}}, t_2 \in \mathcal{T}_{t_1}^{M+} \tag{5}$$

$$\sum_{(j,t,t')\in\mathcal{J}_{it_1t_2}} a_{ijtt'}H'_{jtt'} + U'_{t_1t_2} \leq H^{max} + H^{max}(1 - m_{it_1t_2}) \qquad i \in \mathcal{I}, t_1 \in \mathcal{T}_i^{M_{Init}}, t_2 \in \mathcal{T}_{t_1}^{M+} \tag{6}$$

$$\sum_{(j,t,t')\in\mathcal{J}_{it_2T}} a_{ijtt'}H'_{jtt'} + U'_{t_2T} \leq H^{max} + H^{max}(1 - m_{it_1t_2}) \qquad i \in \mathcal{I}, t_1 \in \mathcal{T}_i^{M_{Init}}, t_2 \in \mathcal{T}_{t_1}^{M+} \tag{7}$$

$$\sum_{t\in\mathcal{T}_i^{M_{Init}},t'\in\mathcal{T}_t^{M+}} m_{itt'} = 1 \qquad i \in \mathcal{I} \tag{8}$$

Constraints (2) limit the number of simultaneous checks, (3) enforce aircraft mission requirements and (4) restrict each aircraft to at most one assignment each period. Constraints (5) - (7) limit the total flight hours of each aircraft before the first check, between checks and after the second check. Constraints (8) require a check pattern assignment for each aircraft.

3 Conclusions and future work

The present work proposes a new model for the MFMP Problem, which can be seen as an extended ILP formulation from [3], with a twice-time index formulation. This new formulation induces more variables, but results in better lower bounds (LP-relaxation) compared to [3]. Generic primal heuristics implemented by MILP solvers are less efficient with this new formulation, it is explained with the increasing number of variables. To improve both primal and dual bounds of [3], perspectives are to implement specific matheuristics designed for the extended MILP formulation, using also Machine Learning predictions to guide the search of primal solutions.

References

[1] P. Cho. *Optimal Scheduling of Fighter Aircraft Maintenance*. PhD thesis, MIT, 2011.

[2] G. Kozanidis. A Multiobjective Model for Maximizing Fleet Availability under the Presence of Flight and Maintenance Requirements. *Journal of Advanced Transportation*, 43(2):155–182, 2008.

[3] F. Peschiera, A. Haït, N. Dupin, and O. Battaïa. Long term planning of military aircraft flight and maintenance operations. Technical report, ISAE-SUPAERO, Université de Toulouse, 2019.

[4] F. Peschiera, A. Haït, N. Dupin, and O. Battaïa. Maintenance planning on french military aircraft operations. In *Congrès annuel de la ROADEF*, 2018.

[5] M. Verhoeff, W. J C Verhagen, and R. Curran. Maximizing operational readiness in military aviation by optimizing flight and maintenance planning. *Transportation Research Procedia*, 941–950, 2015.