complex. The objective is to distribute the training in qualifications of onboard complexes between cosmonauts so that the total time of training was minimal.

It can be formulated in different ways [2]:

\[
\begin{align*}
\max_k \tau_k - \min_k \tau_k & \rightarrow \min, \quad k \in \mathcal{K}, \\
\max_k \tau_k & \rightarrow \min, \quad k \in \mathcal{K}, \\
\min_k \tau_k & \rightarrow \max, \quad k \in \mathcal{K}.
\end{align*}
\]

(1)  
(2)  
(3)

where \( \mathcal{K} \) – set of cosmonauts, \( \tau_k \) – total time of training of cosmonaut \( k \).

For this problem, two algorithms are presented. The first one is a heuristic which iteratively by onboard systems choose such qualification to train that provide optimal objective value. The second one consists of a heuristic and exact parts, and is based on the \( n \)-partition problem approach.

Calendar planning.

The next important step of the planing is a calendar scheduling. Once solved the volume problem for each cosmonaut defined set of tasks which they should do. The objective of calendar planing is not defined but now we use the next: minimizing time of preparation of the first crew to start. Planing should comply with resource constraints and deadlines of the preparation of other crews. The problem is formulated as resource constrained project scheduling problem (RCPSP) and integer programming problem.

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Two-station single track railway with a siding scheduling problem

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A railway connection of two stations by a single railway track is usually found on branch lines of railway network and is very common in various manufacturing supply chains. One of the earliest research of single track scheduling problem is the publication of Szpigel [5]. Since this work scheduling problems, where trains are using a single railway track, remained the subject of intensive research. In 2011 Lusby et al. [2] published an article with a survey of publications on railway scheduling methods and models with a section on single track scheduling problems. A literature review on the single track railway scheduling problem can be found in the Ph.D. thesis of Oliveira [3] which is concerned with application of constraint programming method. Sotskov and Gholami [4] considered single track scheduling problem with several stations and proposed heuristic algorithm. The reduction of the two-station single track railway scheduling problem to the single machine scheduling problem with setup-times can be found in recent work of Gafarov et al. [1].

Our paper is concerned with a scheduling problem for two stations with a single railway track with one siding. On single-track railway sidings or passing loops are used to increase the capacity of the line. The problem involves two stations which will be referred to as station A and station B. All trains are split into two sets. The trains, constituting set \( N_1 \), need to travel from station A to station B. The trains, constituting set \( N_2 \), need to travel from station B to station A. All trains are available at the beginning of the planning horizon and have an equal constant speed. The single track, connecting station A and station B, has a siding – a short track at the side of the main railway line that allows two trains to pass each other when they are moving in opposite directions. Since the length of the siding is relatively small, it is assumed that trains pass the siding instantly.

In the schedule it is necessary to specify for each train its departure time.
If a train uses the siding, then its stay time in the siding is also part of the schedule. The objective is to find a schedule that minimises the time needed to complete all transportations. This objective function will be denoted $C_{\text{max}}$ and will be referred to as the makespan.

In our paper we developed exact optimization algorithm by analysing the structure of optimal schedule for the proposed model. The algorithm produces a schedule that completes all transportations between two stations at minimal time. We present algorithm to construct an optimal schedule in $O(1)$ operations. Optimal schedule analyse allows the development of exact optimization algorithms with other models and objective functions, i.e. results can be generalized and used in future work for a number of regular objective functions, commonly used in scheduling.

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