Scheduling sorties for the Australian Air Force is a very complex task, involving considerations of aircraft maintenance, crew training, proficiency maintenance, and long term fleet sustainability. The problem examined at MISG looked at how recent developments in scheduling can be applied to this problem.

The problem was presented by staff from DSTO. DSTO is responsible for a research in a range of defence sciences for the Australian Defence Forces, including the effective management of fleet capability and its efficient maintenance and replacement over a variety of time horizons. This issue affects various types of platform from army trucks and tanks to submarine and ship fleets in the navy and helicopters and aircraft.

A degree of commonality exists in studying all of these assets (platforms) although, of course, important differences emerge at lower levels of detail. Among the common features are issues of efficient scheduled maintenance, effective measures to deal with unscheduled maintenance, and addressing the long term sustainability of capability while meeting budget targets and other constraints. In addressing capability we need to consider crew availability and training on a sustained basis, as well as the operational level and lifetime of the assets.

In this work we focussed on an integrated approach to crew and tail scheduling for a small aircraft or helicopter fleet. We consider operations, maintenance and training activities. Similar scenarios are documented in extant literature and serve as suitable proxies for a number of other capability scenarios.

We focus on the sortie as the basic operation of an asset. This is interpreted here as a single use of a tail (aircraft) from takeoff to landing. Such a sortie could be a training mission for crew, moving emergency staff in a civil defence emergency like disaster recovery, or a mission in hostile territory during active service. While the latter is perhaps the raison d’etre for the fleet, civil defence response to disasters has become a major component in defence force activities. The ability to run sorties is the defining feature of capability here.
The sortie draws on crew who need to be rostered with attention to constraints on availability and training priorities. Crew have restrictions on flight time on a daily, weekly and long term basis. Constraints avoid too much flying time, but also ensure sufficient flying time to meet operational certification. In addition, there is a need to sustain crew numbers by training new crew and bringing existing crews up through successive levels of skills.

The other input factor in a sortie is the platform. Each sortie requires an asset in good order. For aircraft, this relies on an efficient maintenance schedule. In addition to the anticipated downtime, the operational capability is affected by random events like unscheduled maintenance on assets and crew downtime due to illness. The duration of these events is also unknown.

The planning horizon on such a schedule will vary from a daily plan through weekly and monthly schedules (which assist in rostering) to annual schedules over entire asset lifetimes – typically about 25 years. This latter horizon needs to underlie the planning at shorter times to ensure the constraint on fleet sustainability is met.

As with all complex scheduling tasks, issues arise with respect to optimality versus feasibility. In complex cases such is this, even finding a solution that satisfies all constraints can be difficult. To obtain an optimal solution in reasonable time is often unachievable in practice.

A major issue in the problem studied is identifying the appropriate objective. Ironically this can be more straightforward in related problems in the civilian sector. A commercial airline needs to manage its flight assets and crew in a similar fashion, but the company goal is a direct maximisation of profit. For the defence forces there are certainly issues of cost minimisation, but the real aim is to maximise the capability, which cannot be so simply defined. In some ways this can yield goal optimization tasks where several non competing objectives are being sought and balanced.

There is an opportunity to partition the problem into components which are handled separately, and in the private sector we see this with crew scheduling, tail maintenance, and operational dispatch run separately and meshed later. This decoupling may remove a level of optimality but provide for more rapid solution. At the interface such an approach may be iterative with the components feeding data to one another.

The problem has a large number of decision variables. These key variables include: which sorties to run and when, which assets and crew to assign to the sorties, and how to manage backup for them. There are also very important decision variables in maintenance planning: the timing of maintenance, the allocation of tails to maintenance lines. Other decision variables for crews include: timing and type of training, and timing of leave. In addition to this, many real problems involve use of several bases, including forward bases with limited capacity to perform maintenance, and with restrictions on sorties types. Hence there are also decision variables concerning where maintenance and sorties are performed, and when transfers of crew and aircraft occur.
A number of approaches were suggested in handling this problem. Constraint Programming is a technique that is well suited to scheduling problem such as this with a large number of complicated constraints in each part of the problem. However, trying to capture the entire problem in a single model led to a very cumbersome formulation. A more partitioned model is indicated – an approach that matches the way scheduling is done in practice.

In the scheduling literature, some aspects of the problem have been isolated and solved using mixed integer programming, with solutions available in reasonable time for small problems. There are also examples of heuristic methods that offer rapid solution, for even larger problems (up to 12 platforms). While these could not guarantee optimality, ancillary tests showed the solutions are near optimal.

We elected to run a sample scenario that gave some of the flavour of the problem. It comprised 12 platforms and four bases – a home base, a deep maintenance base and two operational bases. Two normal maintenance lines were at home base and one at an operational base. The maintenance base had one line. Planned maintenance was scheduled after platform use of 200 hours, 400 hours, 600 hours and 1600 hours. Each of these had increasing durations. As a typical platform life of 15 000 operation hours was suggested and there were 100 quarters in 25 year lifetimes, sustainability required that asset use average about 1% per quarter.

One scheduling model was brought to the group by DSTO. This model looked at the ratio of a platform’s residual flight time (RFT - i.e. flight time before next service) to the time the maintenance line would be free. The intent was to reduce maintenance line queues, keep deep maintenance busy. It included a requirement that craft were rotated to fly at least once in some specified period. Crew were assumed on hand for this model. DSTO plans to extend the model to consider stochastic elements.

A method was developed during the week that used a flowchart diagram to impose a degree of maintenance regularity. Superimposed on this was a linear programming method to provide slot assignments, driven by maintenance needs. This model also assumed crew availability. This is an example of an “optimization-based” method (optimization of a subproblem) that, while heuristic, seeks near-optimal solutions.

A third model in mixed integer program form was also developed. This was quite rapid in execution and allowed for some stochastic features using slack. The tail’s RFT was tracked effectively but no crew components were dealt with in this model.

Another linear programming-based model was produced which heuristically matched tails to maintenance lines to provide a daily schedule. This model incorporated unpredictability but again excluded crew constraints.

The variety of approaches developed attests to the complexity of the task at hand. Crewing aspects in particular proved to be very difficult incorporate into a general model, which seems to indicate a partitioning of the problem is necessary for tractable solution. It is also clear that day-to-day decisions affect long-term fleet sustainability – a kind of scheduling “butterfly effect.” Further work is still required to properly examine this complex system.