# Weapon Allocation Project

Matching Blue Effects/Weapons to Red Targets

## Introduction

As a application of your discrete math course, you'll be applying discrete math principles to a real, though simplified, Air Force problem: that of pairing blue effects to targets. Although this particular problem makes us think of the analyst in the Air Operations Center (AOC) or the weapons school graduate in the flying squadron, the theory you'll apply is relevant across the force. A logistician thinking about where to preposition supplies, an acquisitions officer thinking about how to assign capability gaps to acquisition programs, an intel officer thinking about how to allocate taskings to collection platforms, or a personnelist assigning deployment taskings to service members could all benefit from the perspective you'll gain through this project.

## Purpose

Cadets will learn about Hall's condition and the Gale-Shapley algorithm solution to the stable marriage problem and apply them to matching blue military effects to red targets.

## Background

For our project we will explore pairing of BLUE effects (think kinetic effects like munitions and non-kinetic effects like jamming (an example of electronic warfare), influence operations (e.g. deception), or cyber attack) with RED targets. A target is an entity or object considered for possible engagement or other actions. Joint doctrine describes entities as facilities, individuals, virtual (nontangible) things, equipment, or organizations. Any potential target derives its importance only by the extent to which it enables adversary capabilities and actions that must be affected to achieve objectives. The selection and prioritization of targets is a field unto itself, as is determining how effective a given effect will be at achieving the desired objective against a given target. For our purposes, we'll focus on the **allocation** of effects against targets.

I addition to the fact that not all BLUE effects are effective against all RED targets, BLUE effects also have preferences for which target they are most suited to impact. Some possible factors that could come into this prioritization could include range (how easily can I reach the target), timeliness (how likely am I to reach the target before it moves), survivability (how likely am I to survive to the target), and lethality (How likely am I to create the desired effect on the target). In a similar way, each RED target has preferences for which effect it is most suited to be serviced by. Some considerations when prioritizing effects from the target's perspective could be desirability of effect (how well suited is the effect to my objective), target value (how large is the impact on RED versus the cost of the effect), and proportionality (how many unintended consequences are expected from the effect). Clearly neither list is complete, but as we're focusing on the allocation problem, you will always be given the preferences, and won't need to worry about how they were developed.

# Concept of Execution

The project will require you to study Hall's criteria, the stable marriage problem, and the Gale-Shapley algorithm outside of class time; develop software to analyze the feasibility of matchings, analyze the stability of matchings, and to pair effects with targets; and finally write a professional report detailing your research, methodology, results, and recommendations.

You will form groups of 2-3 cadets to complete all phases of the project. You may form groups across sections, but all members of a group must have the same instructor.

The project will consist of three phases with a submission at the completion of each phase. The first two phases are intended as progress checks. Thus, they will consist of questions intended to assure you have achieved adequate progress through the project and will be graded for progress only. The final phase will focus on the content of your final report which will be graded for quality (accuracy, professionalism, communication, etc.).

## Phase 0:

### Complete at 2300 hrs Wednesday 31 January

Instructors will release all project materials to cadets.

Cadets will form groups and report group members to instructors via this spreadsheet on MS Teams.

Cadets will begin to familiarize themselves with the stable marriage problem and project expectations.

## Phase 1

### Complete at 2300 hrs Wednesday 7 February

Instructors will provide cadets sets of incomplete effect and target preferences.

Cadets will develop software to determine if a complete matching exists given an incomplete bipartite graph.

Cadets will identify when complete matchings do or do not exist in incomplete bipartite graphs.

Instructors will provide cadets sets of complete effect and target preferences as well as proposed matchings for each set.

Cadets will develop software to identify stable matchings and rogue couples.

Cadets will determine stability of proposed matchings and identify rogue couplings

Cadets will submit code and results via gradescope.

## Phase 2:

### Complete at 2300 hrs Thurs 15 February

Instructors will provide cadets sets of complete effect and target preferences.

Cadets will implement the Gale-Shapley algorithm

Cadets will develop effect-optimal and target-optimal stable matchings.

Cadets will submit code and results via gradescope.

### Phase 3:

### Complete at 2300 hrs Monday 4 March

Cadets will write a report discussing the application of the Gale-Shapley algorithm and Hall's condition in weapon allocation operations.

Cadets will submit report via gradescope.

## Resources

All data (preferences and pairings) will be provided as comma separated value (CSV) files via MS Teams.

A template file will be provided with Python code to handle the import of provided data and export of results.

You are encouraged to reference the following videos from MIT OpenCourseWare:

- 2.11.1 Stable Matching: Video https://www.youtube.com/watch?v=RE5PmdGNgj0
- 2.11.2 Matching Ritual: Video https://www.youtube.com/watch?v=6vgHIImFwHo
- 2.11.5 Optimal Stable Matching: Video https://www.youtube.com/watch?v=n4KKgKpp--0
- 2.11.7 Bipartite Matching https://www.youtube.com/watch?v=HZLKDC9OSaQ
- 2.11.9 Hall's Theorem https://www.youtube.com/watch?v=i5AWE-OoOsY

You are also encouraged to reference "The Stable Marriage Problem" by D. G. McVitie and L. B. Wilson at http://assets.cs.ncl.ac.uk/TRs/12.pdf and "Distributed Stable Marriage with Incomplete List and Ties using Spark" by Yilong Geng and Mingyu Gao at https://stanford.edu/~rezab/classes/cme323/S15/projects/stable_marriage_spark_report.pdf.

You may also find the Spring 2023 CS110 Honors Python Quick Reference Guide helpful getting back into Python.

### Authorized Resources and Documentation Policy

As you will see in gradescope, the standard authorized resources and documentation policy remains in effect for this project, though slightly reworded to apply to a group assignment.

**Make sure to cite your sources** in accordance with the Dean's Academic Honor Memorandum and Academic Honor Principles and Guidance.  **Citations don't undermine your credibility, they help it**—use them!

You are not required to cite the videos or papers listed above or the course textbook unless you explicitly reference them in your submission.  You may certainly choose to cite any or all of these in particular instances if you think a citation will save writing space or bolster your argument.

As always, **your integrity is the most important part of this project**.  Do not steal someone else's intellectual property or jeopardize your integrity.