1. Introduction

**Conflicting Objectives for Landing Sites**

- **Technical requirement**: Minimize continuous night length
  - **Continuous nights**
    - Daytime and Night alternate
  - **Night**
    - Can't generate electricity all the time
    - Run out of power
  - **Can generate electricity during daytime**
  - Long daytime & short continuous night site is good

- **Mission requirement**: Minimize the distance between landing site and ice
  - Less ice exists at illuminated sites

**Requirements for landing sites**
- Minimize continuous night length
- Maximize communicable time between moon and the Earth
- Minimize slope angles
- Minimize the distance between the landing site and ice etc...

Use Multi-Objective Optimization to select sites that satisfy all the requirements.

**What is Multi-Objective Optimization?**

- **Advantages of Multi-Objective Optimization**
  - No need weighting factors
  - Each objective value is evaluated separately
  - Find several optimal solutions at once
  - We can choose any favorable optimal solution

- **How to select multi-objective optimal solutions**
  - Pareto ranking
    - Each solution’s rank is defined as \( r(X) = 1 + n_i \)
      - \( i \) : the order of the solution
      - \( n_i \) : The number of solutions that are superior to \( X \)
    - No need to compare between objective values that have different units
    - Rank 1 solutions form a Pareto frontier
      - Multi-objective optimal solutions exist on the Pareto frontier

2. Method

**Create Moon Database**
- Calculate moon data by moon simulator
  - The amount of sunshine
  - Communicability
  - Slope angles

**Check Constraints**
- **Constraint 1**: Slope angles < 15.0 degrees
- **Constraint 2**: Continuous night length < 14 days

**Calculate Objective Functions**
- **Minimum objective value is the best**
  - Continuous night length
    - (Max night length) / (Constraint night length)
  - Communicable day length
    - 1.0 – (Illuminative & Communicable day) / 365
  - Slope angles
    - (Slope angles) / (Constraint slope angles)
  - Ice distribution
    - (3D distance from ice) x (depth of ice)

**Divided landing sites by objective functions**

- **Sunshine**: 17413 sites
- **Communication**: 11424 sites
- **Slope**: 11402 sites
- **Ice distribution**: 11803 sites
- **Landing sites**: 0

### Multi-Objective optimal solutions

- **A**: At the South Pole
  - (Within 20 km)
- **B**: Around the South Pole
  - (Within 20 km)
- **C**: Top of the mountains & Facing the Earth

**Conclusion**

- Search landing sites that satisfy conflicting objectives by multi-objective optimization
- Classify multi-objective optimal landing sites by objectives
  - Analyze missions suitable for each site
  - At the South Pole: Extremely narrow, but desirable sites for lunar exploration
  - Around the South Pole (Within 20 km): Suitable for missions using high autonomy rovers
  - Top of mountains & Facing the Earth: Suitable for explorers that communicate with the Earth and are controlled by human frequently