
HEURISTIC ANALYSIS

For Deterministic Logistics Planning Problems for an Air Cargo Transport
System using a Planning Search Agent

Submitted by
Sumit Binnani
as part of Artificial Intelligence Nanodegree, Udacity

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SYNOPSIS

The project defines a group of problems in classical PDDL (Planning Domain Definition Language) for the Air Cargo domain discussed in *Artificial Intelligence: A Modern Approach by Norvig and Russell*. The problem is to be first set up for search, followed by experimental analysis of automatically generated heuristics, including planning graph heuristic.

PROBLEM 1 (P1): INITIAL STATE AND GOAL

```
Init(At(C1, SFO) ∧ At(C2, JFK)
    ∧ At(P1, SFO) ∧ At(P2, JFK)
    ∧ Cargo(C1) ∧ Cargo(C2)
    ∧ Plane(P1) ∧ Plane(P2)
    ∧ Airport(JFK) ∧ Airport(SFO))

Goal(At(C1, JFK) ∧ At(C2, SFO))
```

PROBLEM 2 (P2): INITIAL STATE AND GOAL

```
Init(At(C1, SFO) ∧ At(C2, JFK) ∧ At(C3, ATL)
    ∧ At(P1, SFO) ∧ At(P2, JFK) ∧ At(P3, ATL)
    ∧ Cargo(C1) ∧ Cargo(C2) ∧ Cargo(C3)
    ∧ Plane(P1) ∧ Plane(P2) ∧ Plane(P3)
    ∧ Airport(JFK) ∧ Airport(SFO) ∧ Airport(ATL))

Goal(At(C1, JFK) ∧ At(C2, SFO) ∧ At(C3, SFO))
```

PROBLEM 3 (P3): INITIAL STATE AND GOAL

```
Init(At(C1, SFO) ∧ At(C2, JFK) ∧ At(C3, ATL) ∧ At(C4, ORD)
    ∧ At(P1, SFO) ∧ At(P2, JFK)
    ∧ Cargo(C1) ∧ Cargo(C2) ∧ Cargo(C3) ∧ Cargo(C4)
    ∧ Plane(P1) ∧ Plane(P2)
    ∧ Airport(JFK) ∧ Airport(SFO) ∧ Airport(ATL) ∧ Airport(ORD))

Goal(At(C1, JFK) ∧ At(C3, JFK) ∧ At(C2, SFO) ∧ At(C4, SFO))
```

UNINFORMED NON-HEURISTIC SEARCH

The uninformed non-heuristic planning was experimented with for **Breadth First Search** (BFS), **Depth First Search** (DFS) and **Uniform Cost Search** (UCS). The results for the same can be summarized in Table 1.

Table 1 Metrics for Uninformed Non-Heuristic Search

Problem	Search Type	Plan Length	Time Elapsed (seconds)	# Nodes Expanded	# Goal Tests	Is Optimal
P1	BFS	6	0.03205	43	56	Yes
P1	DFS	12	0.00836	12	13	No
P1	UCS	6	0.04016	55	57	Yes
P2	BFS	9	14.4875	3346	4612	Yes
P2	DFS	1085	8.35226	1124	1125	No
P2	UCS	9	45.70859	4853	4855	Yes
P3	BFS	12	108.85704	14663	18098	Yes
P3	DFS	596	3.41861	627	628	No
P3	UCS	12	386.41591	18235	18237	Yes

It can be seen from the Table 1 that number of **Nodes Expanded** and number of **Goal Tests** bears resemblance. This is as expected since the goal test is performed for every node search.

1. EXECUTION TIME

The time analysis for each of the problem and type of search has been succinctly represented in Figure 1.

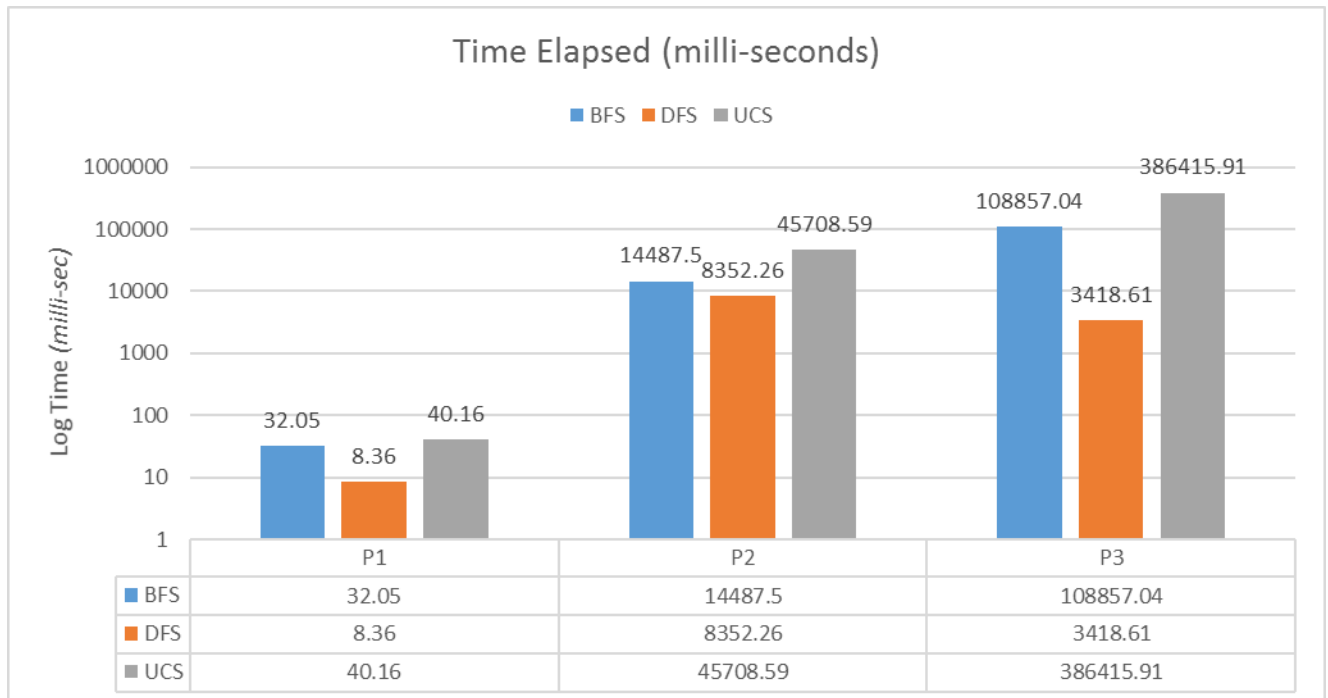


Figure 1 Time Analysis for Uninformed Non-Heuristic Search

It can be seen from the analysis that time taken to reach goal state by DFS in comparison to BFS and UCS is the lowest (*note that the scale is logarithmic*). Also, in all the cases the time taken is as follow:

$$UCS > BFS > DFS$$

Thus, DFS is the fastest planning search among DFS, BFS and UCS.

2. NODES EXPANDED

The memory required by the search can be analyzed by number of nodes expanded by the algorithm. Figure 2 represents the number of nodes expanded for each of the problem for BFS, DFS and UCS (*note that the scale is logarithmic*).

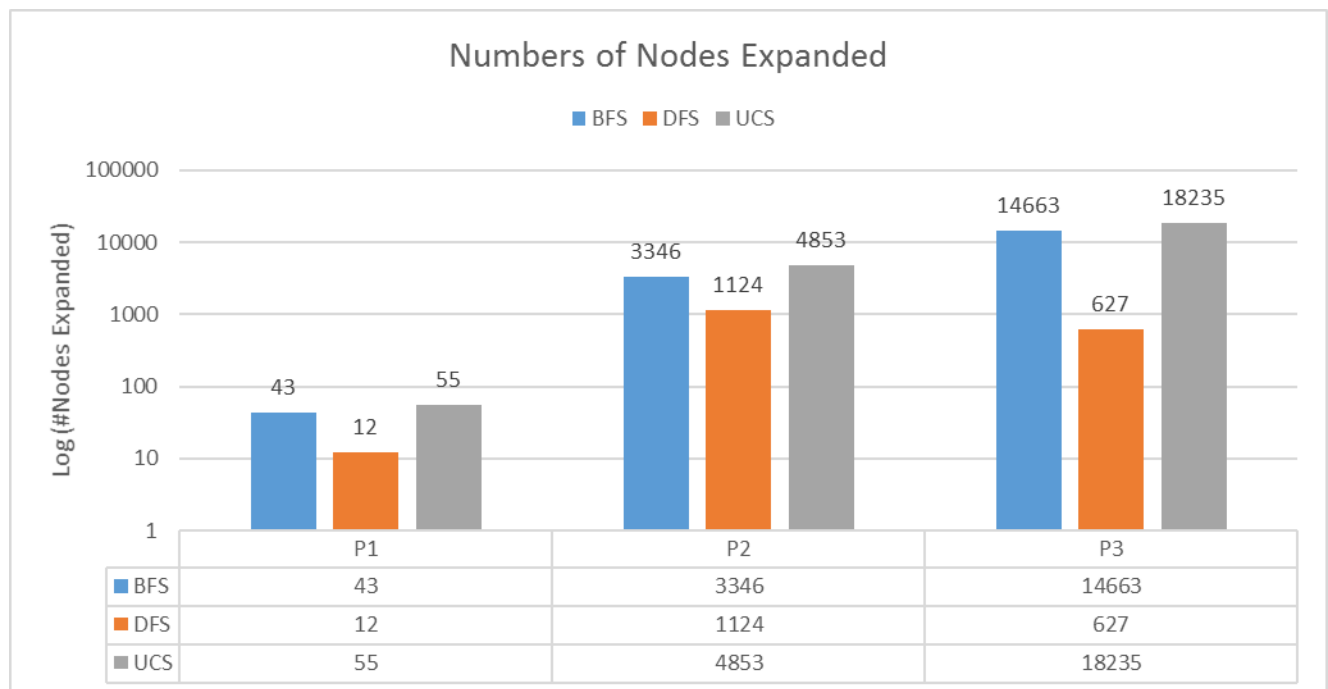


Figure 2 Number of Nodes Expanded during Uninformed Non-Heuristic Search

It can be seen that the number of nodes expanded for each of the problems follow:

$$UCS > BFS > DFS$$

Thus, **DFS expands least number of nodes as compared to BFS and UCS.** This also explains why the time taken for DFS is the least.

3. PATH LENGTH AND OPTIMALITY OF SOLUTION

BFS and UCS provides optimal solution for each of the problems with path length of 6, 9 and 12 for P1, P2 and P3 respectively. The path length of DFS is quite high as compared to BFS or UCS.

HEURISTIC SEARCH

The heuristic planning was experimented with following heuristics:

- h_1 : Technically same as UCS as the heuristic always returns 1
- $h_{\text{ignore_preconditions}}$: Heuristic obtained by *relaxed problem* as defined in "Artificial Intelligence: A Modern Approach" 3rd edition 10.2.3
- $h_{\text{pg_level_sum}}$: Heuristic obtained by planning graph

The search performed during planning was A*-Search and the metrics for the above heuristics were determined by running the search plan on all the problems under consideration.

Table 2 Metrics for Heuristic Search

Problem	A* Heuristic used for Search	Plan Length	Time Elapsed (seconds)	# Nodes Expanded	# Goal Tests	Is Optimal
P1	h_1	6	0.04687	55	57	Yes
P1	$h_{\text{ignore_preconditions}}$	6	0.03333	41	43	Yes
P1	$h_{\text{pg_level_sum}}$	6	2.25789	11	13	Yes
P2	h_1	9	45.57768	4853	4855	Yes
P2	$h_{\text{ignore_preconditions}}$	9	12.87476	1506	1508	Yes
P2	$h_{\text{pg_level_sum}}$	9	245.18644	86	88	Yes
P3	h_1	12	381.39727	18235	18237	Yes
P3	$h_{\text{ignore_preconditions}}$	12	82.61606	5118	5120	Yes
P3	$h_{\text{pg_level_sum}}$	12	1664.45546	408	410	Yes

The metrics for the aforementioned heuristics have been summarized in the Table 2Table 1. It should be noted that the metrics for h_1 is same as that for UCS (see Table 1) as expected. Similar to the non-heuristic search, it can be seen from the table that number of **Nodes Expanded** and number of **Goal Tests** bears resemblance.

1. EXECUTION TIME

The time analysis for each of the problem and type of search has been represented in Figure 3 (*note that the scale is logarithmic*). It can be seen from the analysis that time taken to reach goal state by $h_{\text{ignore_preconditions}}$ heuristics in comparison to h_1 and $h_{\text{pg_level_sum}}$ is the lowest. Also, in all the cases the time taken is as follow:

$$h_{\text{pg_level_sum}} > h_1 > h_{\text{ignore_preconditions}}$$

The advantage of $h_{\text{ignore_preconditions}}$ over h_1 can be attributed to better heuristics. The $h_{\text{pg_level_sum}}$ heuristics suffer from high computation and hence the time taken is higher. In conclusion, it can be stated that **$h_{\text{ignore_preconditions}}$ heuristics provides lowest time for execution.**

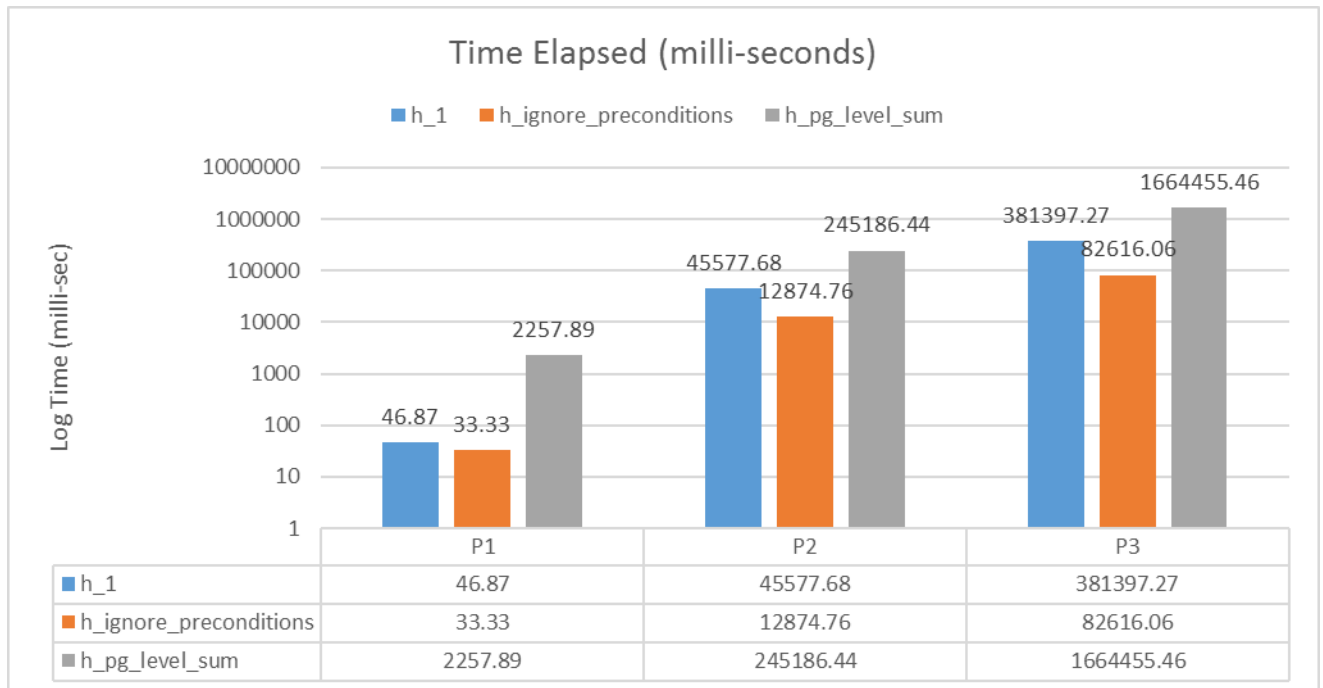


Figure 3 Time Analysis for A* Heuristic Search

2. NODES EXPANDED

The figure like uninformed non-heuristic search can be obtained for heuristic search and has been plotted in Figure 4 (*note that the scale is logarithmic*).

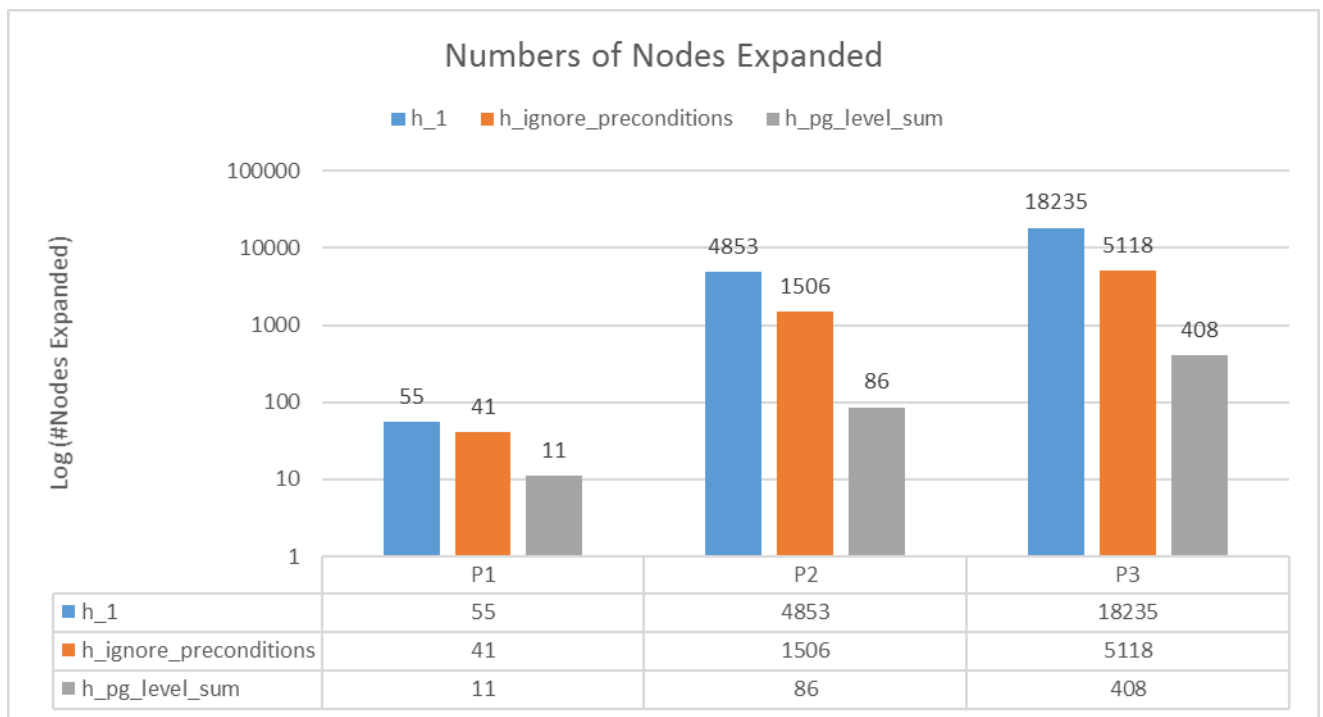


Figure 4 Number of Nodes Expanded during A* Heuristic Search

It can be seen that the number of nodes expanded for each of the problems follow:

$$h_1 > h_ignore_preconditions > h_pg_level_sum$$

Thus, **the number of nodes expanded is least by *h_pg_level_sum* heuristics.**

3. PATH LENGTH AND OPTIMALITY OF SOLUTION

All the heuristics under consideration provide optimal solution for each of the problems with path length of 6, 9 and 12 for P1, P2 and P3 respectively. The optimality of each of the heuristics is guaranteed as all of them are admissible.

4. BEST HEURISTICS: *H_IGNORE_PRECONDITIONS*

Considering balance between time and number of nodes expanded, we can say that *h_ignore_preconditions* heuristics is the best of all heuristics under consideration with lowest execution time and reasonable number of nodes expanded.

Considering optimality of solution, *h_ignore_preconditions* is better than all the non-heuristic search as well as heuristic search discussed in this report (as it takes least time and expands least nodes among all the searches providing optimal solution).

In terms of time taken, DFS all the heuristic as well as non-heuristic algorithms. However, the solution obtained by DFS is not optimal.

OPTIMAL SOLUTIONS

All the optimal solutions reported are by the A*Search using *h_ignore_preconditions* heuristic.

PROBLEM 1 (P1)

```
Load(C1, P1, SFO)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
Load(C2, P2, JFK)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)
```

PROBLEM 2 (P2)

```
Load(C3, P3, ATL)
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)
Load(C2, P2, JFK)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)
Load(C1, P1, SFO)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
```

PROBLEM 3 (P3)

```
Load(C2, P2, JFK)
Fly(P2, JFK, ORD)
Load(C4, P2, ORD)
Fly(P2, ORD, SFO)
Unload(C4, P2, SFO)
Load(C1, P1, SFO)
Fly(P1, SFO, ATL)
Load(C3, P1, ATL)
Fly(P1, ATL, JFK)
Unload(C3, P1, JFK)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)
```

APPENDICES

A. APPENDIX: RAW OUTPUT FOR UNINFORMED NON-HEURISTIC SEARCH

Solving Air Cargo Problem 1 using breadth_first_search...

Expansions	Goal Tests	New Nodes
43	56	180

Plan length: 6 Time elapsed in seconds: 0.03205118500000026

```
Load(C2, P2, JFK)
Load(C1, P1, SFO)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
```

Solving Air Cargo Problem 1 using depth_first_graph_search...

Expansions	Goal Tests	New Nodes
12	13	48

Plan length: 12 Time elapsed in seconds: 0.0083672060000002625

```
Fly(P1, SFO, JFK)
Fly(P2, JFK, SFO)
Load(C1, P2, SFO)
Fly(P2, SFO, JFK)
Fly(P1, JFK, SFO)
Unload(C1, P2, JFK)
Fly(P2, JFK, SFO)
Fly(P1, SFO, JFK)
Load(C2, P1, JFK)
Fly(P2, SFO, JFK)
Fly(P1, JFK, SFO)
Unload(C2, P1, SFO)
```

Solving Air Cargo Problem 1 using uniform_cost_search...

Expansions	Goal Tests	New Nodes
55	57	224

Plan length: 6 Time elapsed in seconds: 0.04016089799984002

```
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P1, SFO, JFK)
Fly(P2, JFK, SFO)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)
```

Solving Air Cargo Problem 2 using breadth_first_search...

Expansions	Goal Tests	New Nodes
3346	4612	30534

Plan length: 9 Time elapsed in seconds: 14.487502968999934

Load(C1, P1, SFO)
Load(C2, P2, JFK)
Load(C3, P3, ATL)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)

Solving Air Cargo Problem 2 using depth_first_graph_search...

Expansions	Goal Tests	New Nodes
1124	1125	10017

Plan length: 1085 Time elapsed in seconds: 8.352262814999904

Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P3, JFK, SFO)
Fly(P2, ATL, SFO)
Fly(P1, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P3, ATL, JFK)
Load(C2, P3, JFK)
Fly(P3, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P1, ATL, SFO)
Fly(P2, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, JFK)
Unload(C2, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P3, JFK, SFO)
Fly(P2, ATL, SFO)
Fly(P1, SFO, ATL)
Fly(P3, SFO, JFK)
Fly(P1, ATL, JFK)
Load(C1, P2, SFO)
Fly(P3, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)

```
Fly(P3, JFK, ATL)
Unload(C1, P2, JFK)
Fly(P3, ATL, SFO)
Fly(P2, JFK, ATL)
Fly(P1, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, JFK)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Load(C1, P3, JFK)
Fly(P3, JFK, ATL)
Fly(P2, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P1, JFK, ATL)
Fly(P2, ATL, JFK)
Load(C3, P1, ATL)
Fly(P1, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, JFK, SFO)
Fly(P2, ATL, SFO)
Fly(P3, SFO, ATL)
Fly(P1, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P1, ATL, JFK)
Unload(C1, P3, JFK)
Fly(P3, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Fly(P3, JFK, ATL)
Unload(C3, P1, SFO)
Fly(P3, ATL, SFO)
Fly(P2, JFK, ATL)
Fly(P1, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, JFK)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, JFK, ATL)
Load(C2, P1, ATL)
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P2, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, SFO)
Fly(P1, JFK, SFO)
Fly(P3, SFO, ATL)
Fly(P1, SFO, ATL)
```

```

Load(C3, P2, SFO)
Fly(P3, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, SFO)
Fly(P1, JFK, ATL)
Fly(P2, JFK, ATL)
Fly(P1, ATL, SFO)
Unload(C3, P2, ATL)
Fly(P2, ATL, JFK)
Fly(P3, SFO, ATL)
Fly(P2, JFK, SFO)
Fly(P3, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P3, JFK, ATL)
Load(C3, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P2, JFK, SFO)
Unload(C2, P1, JFK)
Fly(P3, ATL, JFK)
Fly(P1, JFK, ATL)
Fly(P3, JFK, SFO)
Fly(P1, ATL, SFO)
Fly(P2, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, JFK)
Unload(C3, P3, JFK)
Fly(P3, JFK, ATL)
Fly(P2, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, SFO)
Fly(P1, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, JFK)
Load(C3, P1, JFK)
Fly(P3, ATL, JFK)
Fly(P1, JFK, ATL)
Fly(P3, JFK, SFO)
Fly(P1, ATL, SFO)
Fly(P2, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, JFK)
Unload(C3, P1, SFO)
Fly(P2, JFK, ATL)
Fly(P1, SFO, ATL)
Fly(P2, ATL, SFO)

```

```
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P1, JFK, SFO)
Load(C3, P2, SFO)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P3, JFK, SFO)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P2, JFK, SFO)
Fly(P1, ATL, JFK)
Load(C1, P1, JFK)
Fly(P1, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, SFO)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P3, JFK, SFO)
Fly(P2, ATL, JFK)
Unload(C3, P2, JFK)
Fly(P2, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P3, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P3, JFK, SFO)
Fly(P1, ATL, JFK)
Load(C3, P1, JFK)
Fly(P1, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, SFO)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P3, JFK, SFO)
Fly(P2, ATL, JFK)
Unload(C3, P1, SFO)
Fly(P2, JFK, SFO)
Unload(C1, P1, SFO)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P1, ATL, JFK)
Fly(P3, ATL, SFO)
Fly(P2, JFK, ATL)
Fly(P1, JFK, ATL)
Load(C3, P3, SFO)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Fly(P3, SFO, JFK)
Fly(P2, JFK, ATL)
Fly(P3, JFK, ATL)
```

```

Fly(P2, ATL, SFO)
Load(C1, P2, SFO)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P3, JFK, SFO)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P2, JFK, SFO)
Fly(P1, ATL, JFK)
Unload(C3, P3, SFO)
Fly(P3, SFO, ATL)
Fly(P1, JFK, ATL)
Fly(P3, ATL, JFK)
Fly(P1, ATL, SFO)
Fly(P2, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P2, ATL, JFK)
Load(C2, P2, JFK)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P3, JFK, SFO)
Fly(P2, ATL, SFO)
Fly(P1, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P3, ATL, JFK)
Unload(C2, P2, SFO)
Fly(P1, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P1, ATL, SFO)
Fly(P2, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P2, JFK, SFO)
Unload(C1, P2, SFO)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P3, JFK, SFO)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P2, JFK, SFO)
Fly(P1, ATL, JFK)
Load(C3, P3, SFO)
Fly(P1, JFK, SFO)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P1, ATL, JFK)
Unload(C3, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, JFK, ATL)

```

```

Fly(P2, ATL, SFO)
Fly(P1, ATL, SFO)
Load(C2, P2, SFO)
Fly(P3, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P1, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Load(C3, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, SFO)
Unload(C3, P3, JFK)
Fly(P3, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P2, JFK, SFO)
Fly(P1, ATL, JFK)
Unload(C2, P2, SFO)
Fly(P1, JFK, SFO)
Fly(P2, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P3, ATL, SFO)
Load(C3, P2, JFK)
Fly(P1, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, JFK, SFO)
Fly(P2, ATL, SFO)
Load(C2, P3, SFO)
Fly(P3, SFO, ATL)
Fly(P1, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P2, ATL, JFK)
Unload(C2, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, SFO)
Fly(P3, JFK, SFO)
Fly(P2, SFO, JFK)
Fly(P1, SFO, ATL)
Unload(C3, P2, JFK)

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Fly(P1, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P3, ATL, JFK)
Fly(P1, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P1, ATL, SFO)
Fly(P2, ATL, JFK)
Fly(P3, JFK, ATL)
Load(C2, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, JFK)
Unload(C2, P3, JFK)
Fly(P3, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P1, ATL, SFO)
Load(C1, P3, SFO)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Unload(C1, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P3, JFK, ATL)
Load(C1, P2, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P3, JFK, SFO)
Fly(P2, JFK, ATL)
Fly(P1, JFK, SFO)
Unload(C1, P2, ATL)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Load(C3, P2, JFK)
Fly(P1, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, JFK, SFO)
Fly(P2, ATL, SFO)
Fly(P3, SFO, ATL)
Fly(P2, SFO, JFK)
Fly(P3, ATL, JFK)
Load(C2, P3, JFK)
Fly(P3, JFK, ATL)
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Fly(P2, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, SFO)
Fly(P1, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P1, JFK, ATL)
Unload(C3, P2, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P2, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, SFO)
Fly(P1, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, SFO)
Fly(P3, ATL, JFK)
Unload(C2, P3, JFK)
Fly(P3, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P1, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P3, ATL, SFO)
Fly(P2, JFK, SFO)
Load(C2, P1, JFK)
Fly(P1, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, SFO)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P3, JFK, SFO)
Fly(P2, ATL, JFK)
Unload(C2, P1, SFO)
Fly(P2, JFK, SFO)
Load(C2, P2, SFO)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P3, JFK, SFO)
Fly(P2, JFK, ATL)
Fly(P1, ATL, JFK)
Unload(C2, P2, ATL)
Fly(P2, ATL, JFK)
Fly(P1, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, SFO)
Fly(P3, ATL, JFK)
Fly(P2, JFK, SFO)

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Fly(P1, SFO, ATL)
Load(C3, P1, ATL)
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, JFK)
Fly(P1, JFK, SFO)
Fly(P2, JFK, SFO)
Unload(C3, P1, SFO)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P1, ATL, JFK)
Fly(P3, ATL, SFO)
Fly(P2, JFK, ATL)
Fly(P1, JFK, ATL)
Load(C2, P2, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P2, JFK, SFO)
Fly(P1, JFK, SFO)
Fly(P3, SFO, ATL)
Fly(P1, SFO, ATL)
Fly(P3, ATL, JFK)
Unload(C2, P2, SFO)
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, JFK)
Fly(P1, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, SFO)
Fly(P3, ATL, JFK)
Load(C3, P1, SFO)
Fly(P2, JFK, ATL)
Fly(P3, JFK, ATL)
Fly(P2, ATL, SFO)
Fly(P3, ATL, SFO)
Fly(P1, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P3, SFO, ATL)
Fly(P1, JFK, ATL)
Unload(C3, P1, ATL)
Fly(P3, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P3, JFK, ATL)

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Fly(P2, ATL, SFO)
Load(C3, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P1, JFK, ATL)
Fly(P3, JFK, SFO)
Fly(P1, ATL, SFO)
Fly(P2, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, JFK)
Unload(C3, P3, JFK)
Fly(P3, JFK, ATL)
Fly(P2, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, SFO)
Fly(P1, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, JFK)
Load(C1, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P1, JFK, ATL)
Fly(P3, JFK, SFO)
Fly(P2, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, JFK, SFO)
Fly(P3, SFO, JFK)
Fly(P2, JFK, ATL)
Unload(C1, P3, JFK)
Fly(P2, ATL, SFO)
Fly(P3, JFK, ATL)
Fly(P1, SFO, ATL)
Fly(P3, ATL, SFO)
Fly(P1, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, JFK)
Fly(P1, JFK, ATL)
Load(C3, P3, JFK)
Fly(P1, ATL, SFO)
Fly(P3, JFK, ATL)
Fly(P2, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, SFO)
Fly(P1, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
Load(C1, P3, JFK)
Fly(P2, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P1, JFK, ATL)

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Fly(P3, ATL, SFO)
Fly(P1, ATL, SFO)
Fly(P2, JFK, ATL)
Load(C2, P3, SFO)
Fly(P2, ATL, SFO)
Fly(P3, SFO, ATL)
Fly(P1, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)
Fly(P2, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P2, ATL, SFO)
Fly(P3, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P3, ATL, JFK)
Fly(P1, JFK, SFO)
Fly(P2, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P2, ATL, JFK)
Unload(C2, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, JFK)
Fly(P3, JFK, SFO)
Fly(P2, SFO, ATL)
Fly(P3, SFO, ATL)
Load(C2, P2, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, JFK, ATL)
Fly(P3, JFK, ATL)
Fly(P1, ATL, SFO)
Fly(P3, ATL, SFO)
Fly(P2, JFK, ATL)
Fly(P1, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, JFK)
Load(C3, P3, SFO)
Fly(P1, JFK, SFO)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P1, ATL, JFK)
Unload(C3, P3, ATL)

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Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, SFO)
Fly(P3, JFK, SFO)
Fly(P2, SFO, ATL)
Load(C3, P2, ATL)
Fly(P2, ATL, JFK)
Fly(P3, SFO, ATL)
Fly(P2, JFK, SFO)
Fly(P3, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P2, SFO, JFK)
Fly(P1, ATL, JFK)
Unload(C1, P3, JFK)
Fly(P3, JFK, ATL)
Fly(P2, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, SFO)
Fly(P1, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, SFO)
Unload(C3, P2, SFO)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P1, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P3, ATL, SFO)
Fly(P2, JFK, ATL)
Load(C1, P1, JFK)
Fly(P2, ATL, SFO)
Fly(P1, JFK, ATL)
Unload(C2, P2, SFO)
Fly(P1, ATL, SFO)
Load(C2, P3, SFO)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P1, ATL, JFK)
Fly(P3, ATL, SFO)
Fly(P2, JFK, ATL)
Fly(P1, JFK, ATL)
Unload(C1, P1, ATL)
Fly(P1, ATL, SFO)
Fly(P2, ATL, JFK)
Fly(P3, SFO, JFK)
Fly(P2, JFK, SFO)
Fly(P1, SFO, ATL)

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Unload(C2, P3, JFK)
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, SFO)
Fly(P1, JFK, ATL)
Load(C1, P1, ATL)
Fly(P1, ATL, JFK)
Fly(P3, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, JFK)
Load(C2, P2, JFK)
Fly(P1, JFK, ATL)
Fly(P3, JFK, ATL)
Fly(P1, ATL, SFO)
Fly(P2, JFK, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C3, P2, SFO)
Fly(P3, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, SFO)
Fly(P1, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Unload(C3, P2, JFK)
Fly(P2, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P2, ATL, SFO)
Fly(P3, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P3, ATL, JFK)
Unload(C1, P1, JFK)
Fly(P1, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P1, ATL, SFO)
Fly(P3, JFK, ATL)
Fly(P1, SFO, JFK)
Unload(C2, P2, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, JFK, ATL)
Fly(P3, JFK, ATL)
Fly(P1, ATL, SFO)
Fly(P3, ATL, SFO)
Fly(P2, JFK, ATL)
Fly(P1, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, JFK)
Load(C1, P1, JFK)
Fly(P1, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, SFO)
Fly(P3, ATL, JFK)

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Load(C3, P3, JFK)
Fly(P3, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P2, JFK, SFO)
Unload(C1, P1, ATL)
Fly(P1, ATL, JFK)
Fly(P3, SFO, ATL)
Fly(P1, JFK, SFO)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P3, JFK, SFO)
Load(C2, P2, ATL)
Fly(P2, ATL, JFK)
Fly(P3, SFO, ATL)
Unload(C2, P2, JFK)
Fly(P3, ATL, JFK)
Fly(P2, JFK, SFO)
Fly(P3, JFK, SFO)
Fly(P1, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P2, SFO, ATL)
Load(C1, P3, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, JFK)
Load(C2, P1, JFK)
Fly(P1, JFK, ATL)
Fly(P2, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P3, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P1, JFK, SFO)
Fly(P2, ATL, JFK)
Fly(P3, JFK, ATL)
Unload(C3, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P3, JFK, SFO)
Fly(P2, ATL, SFO)
Fly(P1, SFO, ATL)
Load(C3, P1, ATL)
Fly(P1, ATL, JFK)
Fly(P3, SFO, ATL)
Fly(P1, JFK, SFO)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P3, JFK, SFO)
Fly(P2, ATL, JFK)
Unload(C1, P3, SFO)

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Fly(P2, JFK, SFO)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P1, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Unload(C3, P1, JFK)
Fly(P3, ATL, SFO)
Fly(P2, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P2, ATL, SFO)
Fly(P3, SFO, ATL)
Fly(P1, ATL, SFO)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
Load(C1, P1, SFO)
Fly(P2, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P1, SFO, ATL)
Fly(P3, ATL, SFO)
Fly(P1, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P3, ATL, JFK)
Fly(P1, JFK, ATL)
Unload(C1, P1, ATL)
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P1, JFK, SFO)
Load(C1, P3, ATL)
Fly(P2, SFO, ATL)
Fly(P1, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P3, JFK, SFO)
Load(C3, P2, JFK)
Fly(P1, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P1, JFK, ATL)
Unload(C1, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P3, JFK, SFO)
Fly(P1, JFK, SFO)
Fly(P2, SFO, JFK)
Fly(P3, SFO, ATL)
Fly(P2, JFK, ATL)
Unload(C2, P1, SFO)
Fly(P3, ATL, JFK)

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```
Fly(P2, ATL, SFO)
Load(C2, P2, SFO)
Fly(P1, SFO, JFK)
Fly(P3, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P1, JFK, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Unload(C3, P2, JFK)
Fly(P1, ATL, SFO)
Fly(P3, JFK, ATL)
Fly(P2, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P1, SFO, JFK)
Fly(P2, ATL, JFK)
Load(C3, P1, JFK)
Fly(P2, JFK, SFO)
Fly(P3, SFO, ATL)
Fly(P1, JFK, ATL)
Fly(P3, ATL, JFK)
Fly(P1, ATL, SFO)
Fly(P2, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P2, ATL, JFK)
Unload(C2, P2, JFK)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P3, JFK, SFO)
Fly(P2, ATL, SFO)
Fly(P1, SFO, JFK)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)
Load(C1, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P1, JFK, ATL)
Fly(P2, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P2, JFK, SFO)
Fly(P3, ATL, SFO)
Fly(P1, ATL, SFO)
Fly(P2, SFO, ATL)
Unload(C3, P1, SFO)
Fly(P3, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P1, SFO, ATL)
Fly(P3, ATL, SFO)
Fly(P1, ATL, JFK)
Load(C2, P1, JFK)
Fly(P1, JFK, ATL)
Unload(C1, P3, SFO)
Fly(P3, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
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Fly(P1, JFK, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Fly(P3, JFK, ATL)
Load(C1, P1, SFO)
Fly(P3, ATL, SFO)
Fly(P2, JFK, ATL)
Fly(P1, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P3, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P3, ATL, JFK)
Fly(P1, JFK, SFO)
Load(C3, P2, SFO)
Fly(P3, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, JFK)
Unload(C2, P1, SFO)
Fly(P3, SFO, ATL)
Fly(P1, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P3, JFK, ATL)
Fly(P2, ATL, SFO)
Fly(P3, ATL, SFO)
Load(C2, P3, SFO)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, JFK, ATL)
Fly(P3, JFK, ATL)
Fly(P1, ATL, SFO)
Unload(C2, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, JFK)
Fly(P3, JFK, SFO)
Fly(P2, SFO, ATL)
Unload(C3, P2, ATL)
Fly(P2, ATL, JFK)
Fly(P3, SFO, ATL)
Load(C3, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, JFK, ATL)
Unload(C3, P3, JFK)
Fly(P2, ATL, JFK)
Unload(C1, P1, ATL)
Fly(P1, ATL, JFK)

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Fly(P3, JFK, ATL)
Fly(P1, JFK, SFO)
Fly(P3, ATL, SFO)
Load(C3, P2, JFK)
Fly(P2, JFK, ATL)
Fly(P1, SFO, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, JFK)
Fly(P3, SFO, JFK)
Fly(P2, SFO, ATL)
Load(C1, P2, ATL)
Fly(P2, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P2, JFK, SFO)
Fly(P1, ATL, JFK)
Unload(C3, P2, SFO)
Fly(P1, JFK, SFO)
Fly(P3, SFO, ATL)
Fly(P1, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P2, ATL, JFK)
Load(C2, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P3, JFK, ATL)
Fly(P1, ATL, SFO)
Load(C3, P1, SFO)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P3, JFK, SFO)
Fly(P2, JFK, SFO)
Fly(P1, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P3, ATL, JFK)
Unload(C2, P3, JFK)
Fly(P3, JFK, ATL)
Fly(P1, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P1, ATL, SFO)
Fly(P2, SFO, JFK)
Load(C2, P2, JFK)
Fly(P1, SFO, ATL)
Fly(P2, JFK, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Fly(P3, SFO, ATL)
Fly(P1, JFK, ATL)

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Fly(P3, ATL, JFK)
Fly(P1, ATL, SFO)
Unload(C2, P2, SFO)
Fly(P1, SFO, JFK)
Fly(P2, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, SFO)
Fly(P1, JFK, ATL)
Fly(P3, SFO, JFK)
Unload(C3, P1, ATL)
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P2, JFK, SFO)
Fly(P3, ATL, SFO)
Fly(P1, JFK, ATL)
Fly(P2, SFO, ATL)
Fly(P1, ATL, SFO)
Fly(P2, ATL, JFK)
Load(C2, P3, SFO)
Fly(P1, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P1, ATL, JFK)
Fly(P3, ATL, JFK)
Fly(P2, JFK, ATL)
Fly(P1, JFK, SFO)
Fly(P2, ATL, SFO)
Fly(P3, JFK, ATL)
Load(C3, P3, ATL)
Fly(P3, ATL, SFO)
Fly(P2, SFO, ATL)
Fly(P1, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Fly(P3, SFO, JFK)
Fly(P2, JFK, ATL)
Fly(P3, JFK, ATL)
Unload(C2, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P1, JFK, ATL)
Fly(P3, JFK, ATL)
Unload(C1, P2, JFK)
Fly(P2, JFK, SFO)
Fly(P3, ATL, JFK)
Fly(P1, ATL, JFK)
Load(C1, P3, JFK)
Fly(P1, JFK, SFO)
Fly(P3, JFK, SFO)
Fly(P1, SFO, ATL)
Unload(C1, P3, SFO)
Fly(P1, ATL, JFK)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)

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Fly(P1, JFK, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, JFK)
Load(C2, P1, ATL)
Fly(P1, ATL, JFK)
Fly(P3, JFK, ATL)
Fly(P2, JFK, ATL)
Unload(C3, P3, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Fly(P3, JFK, SFO)
Fly(P1, JFK, ATL)
Fly(P2, JFK, ATL)
Load(C3, P2, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, JFK)
Fly(P1, ATL, JFK)
Unload(C2, P1, JFK)
Fly(P3, JFK, ATL)
Fly(P2, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P2, ATL, SFO)
Fly(P1, JFK, ATL)
Fly(P2, SFO, JFK)
Load(C1, P3, SFO)
Fly(P2, JFK, ATL)
Fly(P3, SFO, JFK)
Fly(P1, ATL, JFK)
Unload(C3, P2, ATL)
Fly(P2, ATL, SFO)
Fly(P1, JFK, ATL)
Load(C2, P3, JFK)
Fly(P1, ATL, SFO)
Fly(P2, SFO, ATL)
Fly(P3, JFK, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, SFO)
Fly(P1, SFO, ATL)
Fly(P2, JFK, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Unload(C2, P3, SFO)
Fly(P1, JFK, ATL)
Fly(P3, SFO, ATL)
Fly(P2, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, JFK)
Load(C3, P1, ATL)
Fly(P1, ATL, JFK)
Fly(P2, JFK, ATL)
Unload(C1, P3, JFK)
Fly(P2, ATL, SFO)
Fly(P3, JFK, ATL)

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Fly(P1, JFK, ATL)
Fly(P3, ATL, SFO)
Fly(P1, ATL, SFO)
Fly(P2, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, JFK)
Load(C2, P1, SFO)
Fly(P3, JFK, SFO)
Fly(P1, SFO, ATL)
Fly(P2, JFK, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Unload(C3, P1, JFK)
Fly(P1, JFK, SFO)
Fly(P2, SFO, ATL)
Fly(P3, SFO, ATL)
Fly(P2, ATL, JFK)
Fly(P3, ATL, JFK)
Load(C3, P2, JFK)
Unload(C2, P1, SFO)
Fly(P3, JFK, ATL)
Fly(P2, JFK, ATL)
Fly(P1, SFO, ATL)
Fly(P3, ATL, JFK)
Fly(P2, ATL, SFO)
Fly(P1, ATL, JFK)
Unload(C3, P2, SFO)

```

Solving Air Cargo Problem 2 using uniform_cost_search...

Expansions	Goal Tests	New Nodes
4853	4855	44041

Plan length: 9 Time elapsed in seconds: 45.70859239699985

```

Load(C1, P1, SFO)
Load(C2, P2, JFK)
Load(C3, P3, ATL)
Fly(P1, SFO, JFK)
Fly(P2, JFK, SFO)
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)
Unload(C2, P2, SFO)
Unload(C1, P1, JFK)

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Solving Air Cargo Problem 3 using breadth_first_search...

Expansions	Goal Tests	New Nodes
14663	18098	129631

Plan length: 12 Time elapsed in seconds: 108.8570453509999

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Load(C2, P2, JFK)

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Load(C1, P1, SFO)
Fly(P2, JFK, ORD)
Load(C4, P2, ORD)
Fly(P1, SFO, ATL)
Load(C3, P1, ATL)
Fly(P1, ATL, JFK)
Unload(C1, P1, JFK)
Unload(C3, P1, JFK)
Fly(P2, ORD, SFO)
Unload(C2, P2, SFO)
Unload(C4, P2, SFO)

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Solving Air Cargo Problem 3 using depth_first_graph_search...

Expansions	Goal Tests	New Nodes
627	628	5176

Plan length: 596 Time elapsed in seconds: 3.418607922999854

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Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C1, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Unload(C1, P2, JFK)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C2, P1, JFK)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Unload(C2, P1, SFO)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C2, P2, SFO)

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Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Load(C3, P1, ATL)
Fly(P1, ATL, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, SFO)
Fly(P2, ORD, ATL)
Fly(P1, SFO, JFK)
Fly(P2, ATL, SFO)
Unload(C2, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, SFO)
Fly(P2, ATL, JFK)
Fly(P1, SFO, ATL)
Load(C1, P2, JFK)
Fly(P1, ATL, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, SFO)
Fly(P2, ORD, ATL)
Fly(P1, SFO, JFK)
Fly(P2, ATL, SFO)
Unload(C1, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Unload(C3, P1, SFO)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C3, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Unload(C3, P2, JFK)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, SFO)
Load(C2, P2, SFO)
Fly(P1, ATL, ORD)

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Fly(P2, SFO, ORD)
Fly(P1, ORD, SFO)
Fly(P2, ORD, ATL)
Fly(P1, SFO, JFK)
Fly(P2, ATL, JFK)
Unload(C2, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, SFO)
Load(C1, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, SFO, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Unload(C1, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Load(C4, P1, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ATL, ORD)
Fly(P1, ATL, SFO)
Fly(P2, ORD, SFO)
Fly(P1, SFO, JFK)
Fly(P2, SFO, JFK)
Unload(C4, P1, JFK)
Fly(P2, JFK, ORD)
Load(C3, P1, JFK)
Fly(P2, ORD, ATL)
Fly(P1, JFK, ORD)
Fly(P2, ATL, SFO)
Fly(P1, ORD, ATL)
Fly(P2, SFO, JFK)
Fly(P1, ATL, SFO)
Unload(C3, P1, SFO)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C3, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Load(C4, P2, JFK)

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Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Unload(C4, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Unload(C3, P2, JFK)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C4, P2, SFO)
Fly(P2, SFO, ATL)
Fly(P1, JFK, ORD)
Unload(C4, P2, ATL)
Fly(P1, ORD, SFO)
Fly(P2, ATL, ORD)
Fly(P1, SFO, JFK)
Fly(P2, ORD, SFO)
Fly(P1, JFK, ATL)
Fly(P2, SFO, JFK)
Load(C3, P2, JFK)
Fly(P1, ATL, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, SFO)
Fly(P2, ORD, ATL)
Unload(C3, P2, ATL)
Fly(P2, ATL, ORD)
Fly(P1, SFO, ORD)
Fly(P2, ORD, SFO)
Fly(P1, ORD, ATL)
Fly(P2, SFO, JFK)
Fly(P1, ATL, JFK)
Load(C2, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, SFO)
Unload(C2, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, SFO, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
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Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Load(C1, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, SFO)
Unload(C1, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, SFO, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Load(C4, P1, ATL)
Fly(P1, ATL, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, SFO)
Fly(P2, ORD, ATL)
Fly(P1, SFO, JFK)
Fly(P2, ATL, SFO)
Unload(C4, P1, JFK)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Load(C2, P1, SFO)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Unload(C2, P1, JFK)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Load(C1, P1, SFO)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Unload(C1, P1, JFK)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, JFK)

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Fly(P1, ORD, SFO)
Load(C4, P2, JFK)
Fly(P1, SFO, ATL)
Fly(P2, JFK, SFO)
Fly(P1, ATL, ORD)
Unload(C4, P2, SFO)
Fly(P1, ORD, SFO)
Fly(P2, SFO, ORD)
Fly(P1, SFO, ATL)
Fly(P2, ORD, JFK)
Fly(P1, ATL, JFK)
Fly(P2, JFK, ATL)
Load(C2, P1, JFK)
Fly(P2, ATL, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, SFO)
Fly(P1, ORD, ATL)
Fly(P2, SFO, JFK)
Fly(P1, ATL, SFO)
Unload(C2, P1, SFO)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C4, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, JFK, SFO)
Fly(P2, ORD, ATL)
Load(C3, P2, ATL)
Fly(P2, ATL, ORD)
Fly(P1, SFO, ORD)
Fly(P2, ORD, SFO)
Fly(P1, ORD, ATL)
Fly(P2, SFO, JFK)
Fly(P1, ATL, JFK)
Unload(C4, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, SFO)
Unload(C3, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, SFO, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Load(C4, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)

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Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Unload(C4, P2, ATL)
Fly(P2, ATL, ORD)
Fly(P1, ATL, ORD)
Fly(P2, ORD, SFO)
Fly(P1, ORD, SFO)
Fly(P2, SFO, JFK)
Fly(P1, SFO, JFK)
Load(C1, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, SFO)
Unload(C1, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, SFO, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Load(C4, P1, ATL)
Fly(P1, ATL, SFO)
Fly(P2, JFK, ORD)
Fly(P1, SFO, JFK)
Fly(P2, ORD, ATL)
Fly(P1, JFK, ORD)
Fly(P2, ATL, SFO)
Load(C3, P2, SFO)
Fly(P1, ORD, ATL)
Fly(P2, SFO, ORD)
Fly(P1, ATL, SFO)
Fly(P2, ORD, JFK)
Fly(P1, SFO, JFK)
Unload(C3, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, ORD)
Fly(P2, ATL, SFO)
Fly(P1, ORD, SFO)
Unload(C4, P1, SFO)
Fly(P2, SFO, ORD)
Fly(P1, SFO, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Load(C3, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)

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Fly(P2, ATL, SFO)
Fly(P1, ATL, SFO)
Unload(C3, P2, SFO)
Fly(P1, SFO, ORD)
Load(C4, P2, SFO)
Fly(P1, ORD, ATL)
Fly(P2, SFO, JFK)
Fly(P1, ATL, SFO)
Fly(P2, JFK, ORD)
Load(C3, P1, SFO)
Fly(P2, ORD, ATL)
Fly(P1, SFO, ORD)
Fly(P2, ATL, SFO)
Fly(P1, ORD, ATL)
Fly(P2, SFO, JFK)
Fly(P1, ATL, JFK)
Unload(C4, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, SFO)
Fly(P2, ATL, SFO)
Fly(P1, SFO, ATL)
Load(C2, P2, SFO)
Fly(P1, ATL, ORD)
Fly(P2, SFO, ORD)
Fly(P1, ORD, SFO)
Fly(P2, ORD, ATL)
Fly(P1, SFO, JFK)
Fly(P2, ATL, JFK)
Unload(C2, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, SFO)
Fly(P2, ATL, SFO)
Fly(P1, SFO, ATL)
Load(C1, P2, SFO)
Fly(P1, ATL, ORD)
Fly(P2, SFO, ORD)
Fly(P1, ORD, SFO)
Fly(P2, ORD, ATL)
Fly(P1, SFO, JFK)
Fly(P2, ATL, JFK)
Load(C4, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, SFO)
Unload(C4, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, SFO, ORD)

```

```

Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Unload(C1, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, SFO)
Unload(C3, P1, SFO)
Fly(P2, SFO, ORD)
Fly(P1, SFO, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Load(C2, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, SFO)
Fly(P1, ATL, SFO)
Unload(C2, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, SFO, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, JFK)
Load(C1, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, SFO)
Load(C2, P2, SFO)
Fly(P1, ATL, ORD)
Fly(P2, SFO, ORD)
Fly(P1, ORD, SFO)
Fly(P2, ORD, ATL)
Fly(P1, SFO, JFK)
Unload(C2, P2, ATL)
Fly(P2, ATL, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, SFO)
Fly(P1, ORD, ATL)
Fly(P2, SFO, JFK)
Fly(P1, ATL, SFO)
Unload(C1, P2, JFK)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)

```



```
Fly(P1, ORD, ATL)
Fly(P2, ORD, SFO)
Fly(P1, ATL, JFK)
Fly(P2, SFO, ATL)
Load(C1, P1, JFK)
Fly(P2, ATL, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, SFO)
Fly(P1, ORD, ATL)
Fly(P2, SFO, JFK)
Fly(P1, ATL, SFO)
Unload(C1, P1, SFO)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C4, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Unload(C4, P2, JFK)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C3, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Unload(C3, P2, JFK)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C1, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Unload(C1, P2, JFK)
```

```

Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C4, P1, JFK)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Fly(P1, ATL, SFO)
Unload(C4, P1, SFO)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, ATL)
Fly(P2, ORD, ATL)
Fly(P1, ATL, JFK)
Fly(P2, ATL, SFO)
Load(C4, P2, SFO)
Fly(P2, SFO, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, JFK)
Load(C2, P1, ATL)
Fly(P1, ATL, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, SFO)
Fly(P2, ORD, ATL)
Unload(C4, P2, ATL)
Fly(P2, ATL, ORD)
Fly(P1, SFO, ORD)
Fly(P2, ORD, SFO)
Fly(P1, ORD, ATL)
Fly(P2, SFO, JFK)
Fly(P1, ATL, JFK)
Load(C3, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, ATL)
Fly(P1, ORD, ATL)
Fly(P2, ATL, SFO)
Unload(C2, P1, ATL)
Fly(P1, ATL, ORD)
Fly(P2, SFO, ORD)
Fly(P1, ORD, SFO)
Fly(P2, ORD, ATL)
Fly(P1, SFO, JFK)
Fly(P2, ATL, JFK)
Unload(C3, P2, JFK)
Fly(P2, JFK, ORD)
Fly(P1, JFK, ORD)

```

```

Fly(P2, ORD, SFO)
Fly(P1, ORD, SFO)
Fly(P2, SFO, ATL)
Load(C2, P2, ATL)
Fly(P2, ATL, ORD)
Fly(P1, SFO, ORD)
Fly(P2, ORD, SFO)
Fly(P1, ORD, ATL)
Unload(C2, P2, SFO)
Fly(P1, ATL, SFO)
Fly(P2, SFO, JFK)
Fly(P1, SFO, ORD)
Fly(P2, JFK, ORD)
Fly(P1, ORD, JFK)
Fly(P2, ORD, ATL)
Load(C4, P2, ATL)
Fly(P2, ATL, ORD)
Fly(P1, JFK, ORD)
Fly(P2, ORD, SFO)
Fly(P1, ORD, ATL)
Unload(C4, P2, SFO)

```

Solving Air Cargo Problem 3 using uniform_cost_search...

Expansions	Goal Tests	New Nodes
18235	18237	159716

Plan length: 12 Time elapsed in seconds: 386.41591021700015

```

Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P1, SFO, ATL)
Load(C3, P1, ATL)
Fly(P2, JFK, ORD)
Load(C4, P2, ORD)
Fly(P2, ORD, SFO)
Fly(P1, ATL, JFK)
Unload(C4, P2, SFO)
Unload(C3, P1, JFK)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)

```

B. APPENDIX: RAW OUTPUT FOR HEURISTIC SEARCH

Solving Air Cargo Problem 1 using astar_search with h_1...

Expansions	Goal Tests	New Nodes
55	57	224

Plan length: 6 Time elapsed in seconds: 0.04686851000042225

```
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P1, SFO, JFK)
Fly(P2, JFK, SFO)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)
```

Solving Air Cargo Problem 1 using astar_search with h_ignore_preconditions...

Expansions	Goal Tests	New Nodes
41	43	170

Plan length: 6 Time elapsed in seconds: 0.03333426499921188

```
Load(C1, P1, SFO)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
Load(C2, P2, JFK)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)
```

Solving Air Cargo Problem 1 using astar_search with h_pg_levelsum...

Expansions	Goal Tests	New Nodes
11	13	50

Plan length: 6 Time elapsed in seconds: 2.2578953800002637

```
Load(C1, P1, SFO)
Fly(P1, SFO, JFK)
Load(C2, P2, JFK)
Fly(P2, JFK, SFO)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)
```

Solving Air Cargo Problem 2 using astar_search with h_1...

Expansions	Goal Tests	New Nodes
4853	4855	44041

Plan length: 9 Time elapsed in seconds: 45.57768660500005

```
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Load(C3, P3, ATL)
```

```
Fly(P1, SFO, JFK)
Fly(P2, JFK, SFO)
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)
Unload(C2, P2, SFO)
Unload(C1, P1, JFK)
```

Solving Air Cargo Problem 2 using astar_search with h_ignore_preconditions...

Expansions	Goal Tests	New Nodes
1506	1508	13820

Plan length: 9 Time elapsed in seconds: 12.874764834000416

```
Load(C3, P3, ATL)
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)
Load(C2, P2, JFK)
Fly(P2, JFK, SFO)
Unload(C2, P2, SFO)
Load(C1, P1, SFO)
Fly(P1, SFO, JFK)
Unload(C1, P1, JFK)
```

Solving Air Cargo Problem 2 using astar_search with h_pg_levelsum...

Expansions	Goal Tests	New Nodes
86	88	841

Plan length: 9 Time elapsed in seconds: 245.1864376100002

```
Load(C1, P1, SFO)
Fly(P1, SFO, JFK)
Load(C2, P2, JFK)
Fly(P2, JFK, SFO)
Load(C3, P3, ATL)
Fly(P3, ATL, SFO)
Unload(C3, P3, SFO)
Unload(C2, P2, SFO)
Unload(C1, P1, JFK)
```

Solving Air Cargo Problem 3 using astar_search with h_1...

Expansions	Goal Tests	New Nodes
18235	18237	159716

Plan length: 12 Time elapsed in seconds: 381.39726624000014

```
Load(C1, P1, SFO)
Load(C2, P2, JFK)
Fly(P1, SFO, ATL)
Load(C3, P1, ATL)
Fly(P2, JFK, ORD)
```

```
Load(C4, P2, ORD)
Fly(P2, ORD, SFO)
Fly(P1, ATL, JFK)
Unload(C4, P2, SFO)
Unload(C3, P1, JFK)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)
```

Solving Air Cargo Problem 3 using astar_search with
h_ignore_preconditions...

Expansions	Goal Tests	New Nodes
5118	5120	45650

Plan length: 12 Time elapsed in seconds: 82.61606033899989

```
Load(C2, P2, JFK)
Fly(P2, JFK, ORD)
Load(C4, P2, ORD)
Fly(P2, ORD, SFO)
Unload(C4, P2, SFO)
Load(C1, P1, SFO)
Fly(P1, SFO, ATL)
Load(C3, P1, ATL)
Fly(P1, ATL, JFK)
Unload(C3, P1, JFK)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)
```

Solving Air Cargo Problem 3 using astar_search with h_pg_levelsum...

Expansions	Goal Tests	New Nodes
408	410	3758

Plan length: 12 Time elapsed in seconds: 1664.4552561989995

```
Load(C2, P2, JFK)
Fly(P2, JFK, ORD)
Load(C4, P2, ORD)
Fly(P2, ORD, SFO)
Load(C1, P1, SFO)
Fly(P1, SFO, ATL)
Load(C3, P1, ATL)
Fly(P1, ATL, JFK)
Unload(C4, P2, SFO)
Unload(C3, P1, JFK)
Unload(C1, P1, JFK)
Unload(C2, P2, SFO)
```