

## INDEX

HEURISTIC ANALYSIS .....	3
Measuring problem-solving performance:.....	3
PROBLEM 1 .....	3
Problem definition.....	3
Optimal Plan.....	4
Comparison of non-heuristic search .....	5
Are heuristic search planning methods better? .....	5
PROBLEM 2 .....	5
Problem definition.....	5
Optimal Plan.....	7
Comparison of non-heuristic search .....	7
Are heuristic search planning methods better? .....	7
PROBLEM 3 .....	8
Problem definition.....	8
Optimal Plan.....	9
Comparison of non-heuristic search .....	9
Are heuristic search planning methods better? .....	10
CONCLUSION.....	10
APPENDIX.....	11
PROBLEM 1 .....	11
Solving Air Cargo Problem 1 using breadth_first_search... ..	11
Solving Air Cargo Problem 1 using breadth_first_tree_search. ....	11
Solving Air Cargo Problem 1 using depth_first_graph_search.. ..	11
Solving Air Cargo Problem 1 using depth_limited_search.....	12
Solving Air Cargo Problem 1 using uniform_cost_search.....	13
Solving Air Cargo Problem 1 using recursive_best_first_search .....	13
Solving Air Cargo Problem 1 using greedy_best_first_graph_search .....	13
Solving Air Cargo Problem 1 using astar_search with h_1.....	13
Solving Air Cargo Problem 1 using astar_search with h_ignore .....	14
Solving Air Cargo Problem 1 using astar_search with h_pg_lev .....	14
PROBLEM 2 .....	14
Solving Air Cargo Problem 2 using breadth_first_search... ..	14
Solving Air Cargo Problem 2 using depth_first_graph_search... ..	14
Solving Air Cargo Problem 2 using depth_first_graph_search... ..	25
Solving Air Cargo Problem 2 using uniform_cost_search.....	36

Solving Air Cargo Problem 2 using greedy_best_first_graph_search with h_1...	37
Solving Air Cargo Problem 2 using astar_search with h_1.....	37
Solving Air Cargo Problem 2 using astar_search with h_ignore_preconditions...	37
PROBLEM 3 .....	38
Solving Air Cargo Problem 3 using breadth_first_search...	38
Solving Air Cargo Problem 3 using depth_first_graph_search...	38
Solving Air Cargo Problem 3 using uniform_cost_search...	51
Solving Air Cargo Problem 3 using greedy_best_first_graph_search with h_1.....	51
Solving Air Cargo Problem 3 using astar_search with h_1.....	52
Solving Air Cargo Problem 3 using astar_search with h_ignore_preconditions.....	53

## HEURISTIC ANALYSIS

Heuristic analysis covers the comparison and contrast heuristic search result metrics using A\* with the "ignore preconditions" and "level-sum" heuristics for Problems 1, 2, and 3.

This project was defined in PDDL as:

```

Action(Load(c, p, a),
  PRECOND: At(c, a) ∧ At(p, a) ∧ Cargo(c) ∧ Plane(p) ∧ Airport(a)
  EFFECT: ¬ At(c, a) ∧ In(c, p))
Action(Unload(c, p, a),
  PRECOND: In(c, p) ∧ At(p, a) ∧ Cargo(c) ∧ Plane(p) ∧ Airport(a)
  EFFECT: At(c, a) ∧ ¬ In(c, p))
Action(Fly(p, from, to),
  PRECOND: At(p, from) ∧ Plane(p) ∧ Airport(from) ∧ Airport(to)
  EFFECT: ¬ At(p, from) ∧ At(p, to))

```

## MEASURING PROBLEM-SOLVING PERFORMANCE:

We can evaluate an algorithm's performance in four ways:<sup>1</sup>

- **Completeness:** Is the algorithm guaranteed to find a solution when there is one?
- **Optimality:** Does the strategy find the optimal solution (goal state reached with the lowest path cost among all solutions)
- **Time complexity:** How long does it take to find a solution?
- **Space Complexity:** How much memory is needed to perform the search?

Complexity is expressed in terms of branching factor, the depth of the shallowest goal node (number of steps along the path from the root); and the maximum length of any path in the state space.

---

### PROBLEM 1

#### PROBLEM DEFINITION

---

Problem 1 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))

```

That is:

- Two cargos [C1, C2]
- Two planes [P1, P2]

---

<sup>1</sup> Artificial Intelligence: A modern Approach. Stuart Russell & Peter Norvig. 3<sup>rd</sup> edition Chapter 3

- Two airports [JFK, CFO]

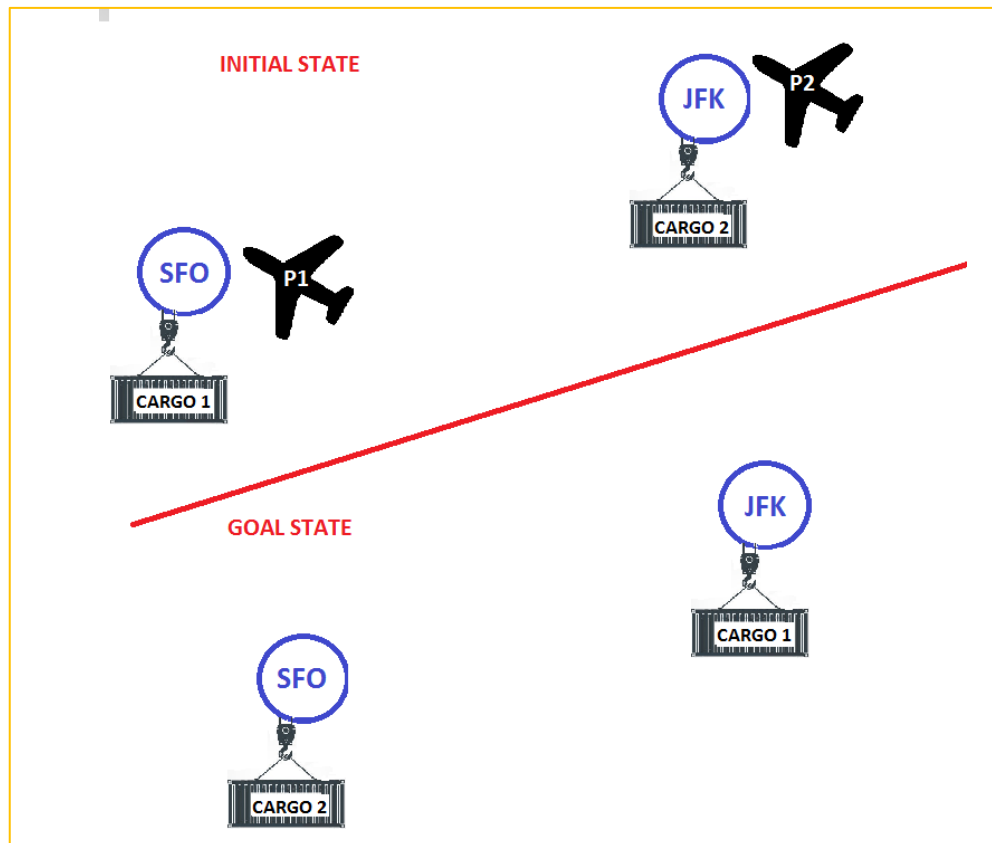


FIGURE 1 PROBLEM 1: INITIAL STATE AND GOAL STATE GRAPHIC REPRESENTATION.

The metrics gathered for Problem 1 are summarised in the following table:

		Expansions	Goal Tests	New Nodes	Plan length	Time (seconds)
1	breadth_first_search	43	56	180	6	0.06817695
2	breadth_first_tree_search	1458	1459	5960	6	1.932569177
3	depth_first_graph_search	21	22	84	20	0.029160107
4	depth_limited_search	101	271	414	50	0.148578431
5	uniform_cost_search	55	57	224	6	0.087215695
6	recursive_best_first_search	4229	4230	17023	6	5.777305052
7	greedy_best_first_graph_search	7	9	28	6	0.012970658
8	astar_search h_1	55	57	224	6	0.081050772
9	astar_search h_ignore_preconditions	41	43	170	6	0.065016618
10	astar_search h_pg_levelsum	45	47	188	6	2.891080564

## OPTIMAL PLAN

The **greedy\_best\_first\_graph\_search** is the optimum. It optimum and the fastest heuristic. The reason remains in the definition of the algorithm itself: It expands the node closest to the goal, leading quickly to a solution. Therefore, expands fewer nodes, take less time and finds quicker a solution.

The steps for the sequence are:

Load(C<sub>1</sub>, P<sub>1</sub>, SFO)  
 Load(C<sub>2</sub>, P<sub>2</sub>, JFK)  
 Fly(P<sub>1</sub>, SFO, JFK)  
 Fly(P<sub>2</sub>, JFK, SFO)  
 Unload(C<sub>1</sub>, P<sub>1</sub>, JFK)  
 Unload(C<sub>2</sub>, P<sub>2</sub>, SFO)

## COMPARISON OF NON-HEURISTIC SEARCH

Regarding the comparison of non-heuristic search result metrics:

		Expansions	Goal Tests	New Nodes	Plan length	Time
1	breadth_first_search	43	56	180	6	0.06817695
3	depth_first_graph_search	21	22	84	20	0.029160107
5	uniform_cost_search	55	57	224	6	0.087215695

In this problem, **depth\_first\_graph\_search** results in less time complexity, less space complexity but needs more steps (not optimum) than **breadth-first search** and **uniform cost search**. The last two are optimum while are a bit more complex. Although **breadth-first search** is faster than **uniform\_cost\_search** there is not a big gap between the two of them considering time and goal test needed.

## ARE HEURISTIC SEARCH PLANNING METHODS BETTER?

		Expansions	Goal Tests	New Nodes	Plan length	Time
8	astar_search h_1	55	57	224	6	0.081050772
9	astar_search h_ignore_preconditions	41	43	170	6	0.065016618
10	astar_search h_pg_levelsum	45	47	188	6	2.891080564

For Heuristic search, the **astar\_search h\_ignore\_preconditions** performs much better while keeping optimum. Comparing it with the fastest non-heuristic & optimum method, **astar\_search h\_ignore\_preconditions**, beats on metrics.

## PROBLEM 2

### PROBLEM DEFINITION

- Problem 2 initial state and goal:

*Init*(At(C<sub>1</sub>, SFO) ∧ At(C<sub>2</sub>, JFK) ∧ At(C<sub>3</sub>, ATL)  
 ∧ At(P<sub>1</sub>, SFO) ∧ At(P<sub>2</sub>, JFK) ∧ At(P<sub>3</sub>, ATL)  
 ∧ Cargo(C<sub>1</sub>) ∧ Cargo(C<sub>2</sub>) ∧ Cargo(C<sub>3</sub>)  
 ∧ Plane(P<sub>1</sub>) ∧ Plane(P<sub>2</sub>) ∧ Plane(P<sub>3</sub>)  
 ∧ Airport(JFK) ∧ Airport(SFO) ∧ Airport(ATL))  
*Goal*(At(C<sub>1</sub>, JFK) ∧ At(C<sub>2</sub>, SFO) ∧ At(C<sub>3</sub>, SFO))

That is:

- Three cargos [C<sub>1</sub>, C<sub>2</sub>, C<sub>3</sub>]
- Three planes [P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub>]
- Three airports [JFK, CFO, ATL]

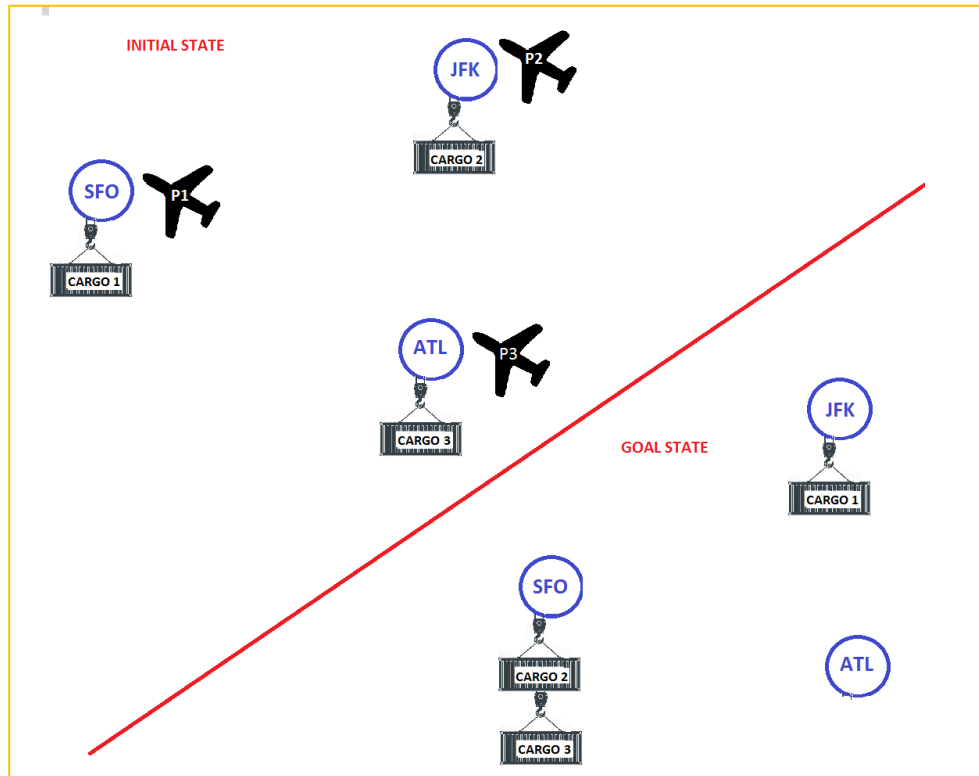


FIGURE 2 PROBLEM 2: INITIAL STATE AND GOAL STATE GRAPHIC REPRESENTATION.

The metrics gathered for Problem 2 are summarised in the following table (where TO = Timed Out):

		Expansions	Goal Tests	New Nodes	Plan length	Time (seconds)
1	breadth_first_search	3343	4609	30509	9	33.79900031
2	breadth_first_tree_search	TO	TO	TO	TO	TO
3	depth_first_graph_search	624	625	5602	619	6.695474237
4	depth_limited_search	TO	TO	TO	TO	TO
5	uniform_cost_search	4853	4855	44041	9	48.80281886
6	recursive_best_first_search	TO	TO	TO	TO	TO
7	greedy_best_first_graph_search	998	1000	8982	21	7.331830368
8	astar_search h_1	4853	4855	44041	9	34.45352545
9	astar_search h_ignore_preconditions	1450	1452	13303	9	17.43890903
10	astar_search h_pg_levelsum	TO	TO	TO	TO	TO

## OPTIMAL PLAN

For this second problem, we find that `depth_first_graph_search` is the less complex in time heuristic. However, it does not find the optimum plan length. This is reached with `breath_first_search`, `uniform_cost_search`, `astar_search h_1` and `astar_search h_ignore_preconditions`. From all of these **`astar_search h_ignore_preconditions`** takes the less time, needs fewer expansions and fewer goal tests to reach the solution. Therefore it is optimum.

The steps for the sequence are:

```
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)
```

## COMPARISON OF NON-HEURISTIC SEARCH

Regarding the comparison of non-heuristic search result metrics:

		Expansions	Goal Tests	New Nodes	Plan length	Time
1	<code>breadth_first_search</code>	3343	4609	30509	9	33.79900031
3	<code>depth_first_graph_search</code>	624	625	5602	619	6.695474237
5	<code>uniform_cost_search</code>	4853	4855	44041	9	48.80281886

The comparison reaches the same conclusion as in problem 1, Depth-first search results in less time complexity, less space complexity but needs more steps (less optimality) than breadth-first search and uniform cost search. The last two are optimum while are a bit much more complex. This time the gap between these two methods clearly makes **`breadth_first_search`** the best non-heuristic method.

## ARE HEURISTIC SEARCH PLANNING METHODS BETTER?

		Expansions	Goal Tests	New Nodes	Plan length	Time
8	<code>astar_search h_1</code>	4853	4855	44041	9	34.45352545
9	<code>astar_search h_ignore_preconditions</code>	1450	1452	13303	9	17.43890903
10	<code>astar_search h_pg_levelsum</code>	TO	TO	TO	TO	TO

Considering Problem 2, we find `astar_search_pg_levelsum` and `uniform_cost_search` having the same complexity and cost metrics. In this specific case `astar_search_pg_levelsum` beats in time complexity its non-heuristic metric-twin method. In both cases there are two methods that are optimum.

As heuristic method we can see **astar\_search h\_ignore\_preconditions** is both the most optimum method between heuristic ones, as well as less complex in space and time. If we compare this one with the optimum in non-heuristic the best performance is reached in **astar\_search h\_ignore\_preconditions** as has fewer expansions and need less goal test with a better time metric..

### PROBLEM 3

#### PROBLEM DEFINITION

- Problem 3 initial state and goal:

$Init(At(C_1, SFO) \wedge At(C_2, JFK) \wedge At(C_3, ATL) \wedge At(C_4, ORD)$   
 $\wedge At(P_1, SFO) \wedge At(P_2, JFK)$   
 $\wedge Cargo(C_1) \wedge Cargo(C_2) \wedge Cargo(C_3) \wedge Cargo(C_4)$   
 $\wedge Plane(P_1) \wedge Plane(P_2)$   
 $\wedge Airport(JFK) \wedge Airport(SFO) \wedge Airport(ATL) \wedge Airport(ORD))$   
 $Goal(At(C_1, JFK) \wedge At(C_3, JFK) \wedge At(C_2, SFO) \wedge At(C_4, SFO))$

That is:

- Four cargos [C1, C2, C3, C4]
- Two planes [P1, P2]
- Four airports [JFK, SFO, ATL, ORD]

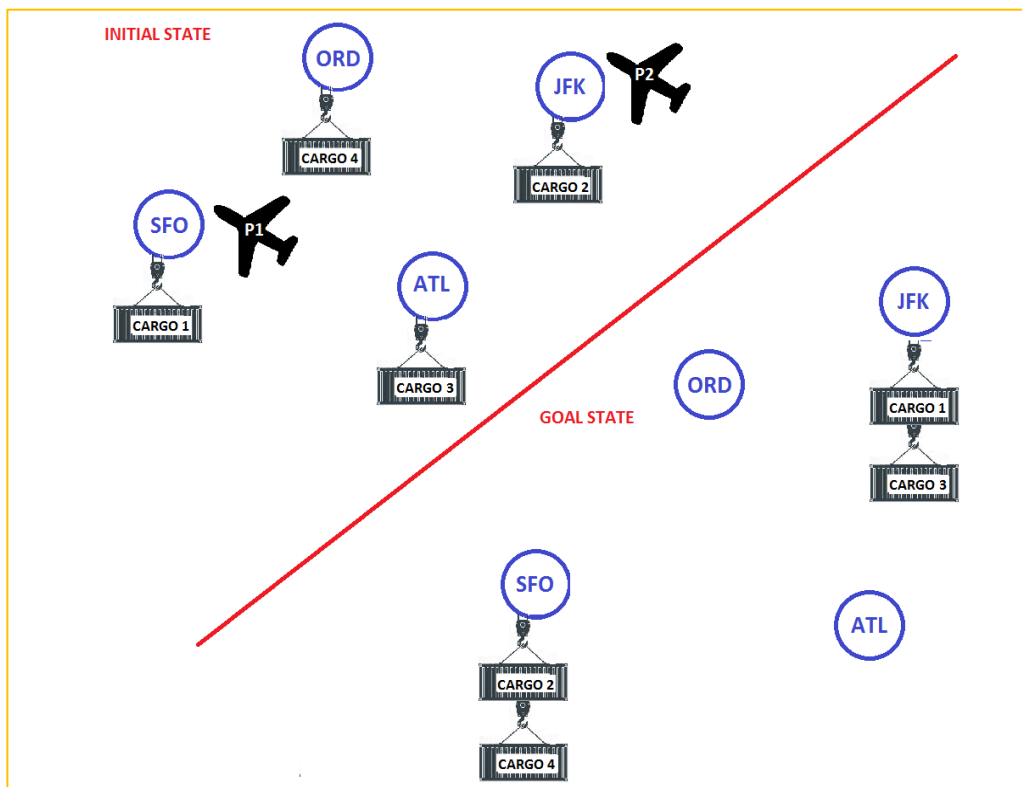


FIGURE 3 PROBLEM 3: INITIAL STATE AND GOAL STATE GRAPHIC REPRESENTATION.

The metrics gathered for Problem 3 are summarised in the following table (where TO = Timed Out):



		Expansions	Goal Tests	New Nodes	Plan length	Time (seconds)
1	breadth_first_search	3343	4609	30509	12	336.2690923
2	breadth_first_tree_search	TO	TO	TO	TO	TO
3	depth_first_graph_search	624	625	5602	392	3.190495443
4	depth_limited_search	TO	TO	TO	TO	TO
5	uniform_cost_search	4853	4855	44041	12	180.3116849
6	recursive_best_first_search	TO	TO	TO	TO	TO
7	greedy_best_first_graph_search	998	1000	8982	22	54.17322964
8	astar_search h_1	4853	4855	44041	12	164.9216165
9	astar_search h_ignore_preconditions	1450	1452	13303	12	57.23769514
10	astar_search h_pg_levelsum	TO	TO	TO	TO	TO

### OPTIMAL PLAN

The optimum is reached in **astar\_search h\_ignore\_preconditions**

The steps for the sequence are:

Load(C<sub>2</sub>, P<sub>2</sub>, JFK)  
 Fly(P<sub>2</sub>, JFK, ORD)  
 Load(C<sub>4</sub>, P<sub>2</sub>, ORD)  
 Fly(P<sub>2</sub>, ORD, SFO)  
 Unload(C<sub>4</sub>, P<sub>2</sub>, SFO)  
 Load(C<sub>1</sub>, P<sub>1</sub>, SFO)  
 Fly(P<sub>1</sub>, SFO, ATL)  
 Load(C<sub>3</sub>, P<sub>1</sub>, ATL)  
 Fly(P<sub>1</sub>, ATL, JFK)  
 Unload(C<sub>3</sub>, P<sub>1</sub>, JFK)  
 Unload(C<sub>2</sub>, P<sub>2</sub>, SFO)  
 Unload(C<sub>1</sub>, P<sub>1</sub>, JFK)

Fastest algorithm is reached in depth\_first\_graph but it is not optimum. From the optimum methods, breadth\_first\_search, uniform\_cost\_search, astar\_search h\_1, astar\_search h\_ignore\_preconditions; **astar\_search h\_ignore\_preconditions** is the fastest as it needs to expand less nodes and needs less goal tests.

### COMPARISON OF NON-HEURISTIC SEARCH

Regarding the comparison of non-heuristic search result metrics:

		Expansions	Goal Tests	New Nodes	Plan length	Time
1	breadth_first_search	3343	4609	30509	12	336.2690923
3	depth_first_graph_search	624	625	5602	392	3.190495443
5	uniform_cost_search	4853	4855	44041	12	180.3116849

Considering the non-heuristic search methods we found two optimum methods: breadth\_first\_search and uniform\_cost\_search.

Comparing them, breadth\_first\_search results results on less space complexity (less expansions and less goal tests) while uniform\_cost\_search results on less time complexity.

#### ARE HEURISTIC SEARCH PLANNING METHODS BETTER?

		Expansions	Goal Tests	New Nodes	Plan length	Time
8	astar_search h_1	4853	4855	44041	12	164.9216165
9	astar_search h_ignore_preconditions	1450	1452	13303	12	57.23769514
10	astar_search h_pg_levelsum	TO	TO	TO	TO	TO

In problem 3, we find that **astar\_search h\_ignore\_preconditions** is optimum and the fastest of heuristic methods. If we compare it with non-heuristic optimum solution astar\_search h\_ignore\_preconditions beat the metrics.

#### CONCLUSION

Considering the comparison of 3 non-heuristic and 3 heuristic methods in all 3 problems the conclusion is that **astar\_search h\_ignore\_preconditions** was optimum while had better metrics.

As stated on Artificial Intelligence a Modern Approach <sup>2</sup> "an admissible heuristic can be derived by defining a relaxed problem easier to solve" like the mentioned **ignore\_preconditions** heuristic.

By removing the precondition, we make much more efficient forward and backward search and therefore we can use A\* search to find optimal solutions.

---

<sup>2</sup> Stuart Russell & Peter Norvig. 3rd Edition (Chapter 10. Classical Planning. Section 10.2.3 Heuristics for planning). Page 376

## APPENDIX

These are the complete results appears on the screen after

```
python run_search.py -p x -s y,
```

where -x- is the number of Problem in [1,2,3]

and -y- the heuristic in [1,2,3,4,5,6,7,8,9,10]

## PROBLEM 1

## SOLVING AIR CARGO PROBLEM 1 USING BREADTH\_FIRST\_SEARCH...

Expansions	Goal Tests	New Nodes
43	56	180

Plan length: 6 Time elapsed in seconds: 0.06817695001660044

Load(C1, P1, SFO)

Load(C2, P2, JFK)

Fly(P2, JFK, SFO)

Unload(C2, P2, SFO)

Fly(P1, SFO, JFK)

Unload(C1, P1, JFK)

## SOLVING AIR CARGO PROBLEM 1 USING BREADTH\_FIRST\_TREE\_SEARCH.

Expansions	Goal Tests	New Nodes
1458	1459	5960

Plan length: 6 Time elapsed in seconds: 1.932569177439105

Load(C1, P1, SFO)

Load(C2, P2, JFK)

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
21	22	84

Plan length: 20 Time elapsed in seconds: 0.0291601068140359

Fly(P1, SFO, JFK)

Fly(P2, JFK, SFO)

Load(C2, P1, JFK)

Fly(P1, JFK, SFO)

Fly(P2, SFO, JFK)

Unload(C2, P1, SFO)

Fly(P1, SFO, JFK)

Fly(P2, JFK, SFO)

Load(C2, P2, SFO)

Fly(P1, JFK, SFO)

Load(C<sub>1</sub>, P<sub>2</sub>, SFO)  
Fly(P<sub>2</sub>, SFO, JFK)  
Fly(P<sub>1</sub>, SFO, JFK)  
Unload(C<sub>2</sub>, P<sub>2</sub>, JFK)  
Unload(C<sub>1</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>2</sub>, JFK, SFO)  
Load(C<sub>2</sub>, P<sub>1</sub>, JFK)  
Fly(P<sub>1</sub>, JFK, SFO)  
Fly(P<sub>2</sub>, SFO, JFK)  
Unload(C<sub>2</sub>, P<sub>1</sub>, SFO)

## SOLVING AIR CARGO PROBLEM 1 USING DEPTH\_LIMITED\_SEARCH...

Expansions   Goal Tests   New Nodes

101      271      414

Plan length: 50 Time elapsed in seconds: 0.1485784308475506

[illegible]

Unload(C1, P1, SFO)  
Load(C1, P1, SFO)  
Unload(C1, P1, SFO)  
Load(C1, P1, SFO)  
Unload(C1, P1, SFO)  
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 UNIFORM\_COST\_SEARCH...

Expansions	Goal Tests	New Nodes
55	57	224

Plan length: 6 Time elapsed in seconds: 0.0872156950944798  
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 RECURSIVE\_BEST\_FIRST\_SEARCH

Expansions	Goal Tests	New Nodes
4229	4230	17023

Plan length: 6 Time elapsed in seconds: 5.777305051889773  
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 GREEDY\_BEST\_FIRST\_GRAPH\_SEARCH

Expansions	Goal Tests	New Nodes
7	9	28

Plan length: 6 Time elapsed in seconds: 0.01297065827005461  
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\_1...

Expansions	Goal Tests	New Nodes
55	57	224

Plan length: 6 Time elapsed in seconds: 0.08105077236686498

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

Expansions   Goal Tests   New Nodes  
41      43      170

Plan length: 6   Time elapsed in seconds: 0.0650166182933116  
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\_LEV

Expansions   Goal Tests   New Nodes  
45      47      188

Plan length: 6   Time elapsed in seconds: 2.8910805639152777  
Load(C1, P1, SFO)  
Fly(P1, SFO, JFK)  
Load(C2, P2, JFK)  
Fly(P2, JFK, SFO)  
Unload(C1, P1, JFK)  
Unload(C2, P2, SFO)

#### PROBLEM 2

---

#### SOLVING AIR CARGO PROBLEM 2 USING BREADTH\_FIRST\_SEARCH...

Expansions   Goal Tests   New Nodes  
3343      4609      30509

Plan length: 9   Time elapsed in seconds: 33.79900031415893  
Load(C1, P1, SFO)  
Load(C2, P2, JFK)  
Load(C3, P3, ATL)  
Fly(P2, JFK, SFO)  
Unload(C2, P2, SFO)  
Fly(P1, SFO, JFK)  
Unload(C1, P1, JFK)  
Fly(P3, ATL, SFO)  
Unload(C3, P3, SFO)

---

#### SOLVING AIR CARGO PROBLEM 2 USING DEPTH\_FIRST\_GRAPH\_SEARCH...

Expansions   Goal Tests   New Nodes  
624      625      5602

Plan length: 619 Time elapsed in seconds: 6.695474237182851

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

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



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

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

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

Load(C<sub>3</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>3</sub>, SFO, JFK)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>3</sub>, JFK, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, JFK, SFO)  
Fly(P<sub>3</sub>, ATL, SFO)  
Fly(P<sub>2</sub>, SFO, ATL)  
Fly(P<sub>1</sub>, SFO, ATL)  
Unload(C<sub>3</sub>, P<sub>2</sub>, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, SFO, ATL)  
Fly(P<sub>3</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, SFO, ATL)  
Fly(P<sub>3</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>3</sub>, ATL, SFO)  
Unload(C<sub>2</sub>, P<sub>1</sub>, JFK)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>1</sub>, JFK, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, SFO, JFK)  
Fly(P<sub>2</sub>, SFO, ATL)  
Load(C<sub>3</sub>, P<sub>2</sub>, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, SFO, JFK)  
Fly(P<sub>3</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, ATL, SFO)  
Unload(C<sub>3</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>1</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, ATL, SFO)  
Load(C<sub>3</sub>, P<sub>1</sub>, JFK)  
Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, SFO, ATL)  
Fly(P<sub>3</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, JFK, ATL)  
Fly(P<sub>3</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, ATL, SFO)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, SFO, ATL)  
Unload(C<sub>1</sub>, P<sub>1</sub>, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, SFO, ATL)

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

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

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



Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, SFO, ATL)  
Fly(P<sub>3</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, SFO, ATL)  
Fly(P<sub>3</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>3</sub>, ATL, SFO)  
Fly(P<sub>2</sub>, JFK, ATL)  
Load(C<sub>3</sub>, P<sub>2</sub>, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, SFO, JFK)  
Fly(P<sub>3</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, JFK, ATL)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>3</sub>, JFK, ATL)  
Load(C<sub>1</sub>, P<sub>3</sub>, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, SFO, ATL)  
Fly(P<sub>1</sub>, SFO, JFK)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, JFK, ATL)  
Fly(P<sub>3</sub>, JFK, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Unload(C<sub>3</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>1</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>3</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Unload(C<sub>1</sub>, P<sub>3</sub>, JFK)  
Fly(P<sub>2</sub>, SFO, ATL)  
Fly(P<sub>1</sub>, SFO, JFK)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>3</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, JFK, ATL)  
Fly(P<sub>3</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Load(C<sub>3</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>3</sub>, SFO, JFK)  
Unload(C<sub>3</sub>, P<sub>2</sub>, SFO)

---

## SOLVING AIR CARGO PROBLEM 2 USING DEPTH\_FIRST\_GRAPH\_SEARCH...

Expansions   Goal Tests   New Nodes

624      625      5602

Plan length: 619 Time elapsed in seconds: 6.466916030316336

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

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

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

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

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

Fly(P<sub>3</sub>, SFO, JFK)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>3</sub>, JFK, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, JFK, SFO)  
Fly(P<sub>3</sub>, ATL, SFO)  
Fly(P<sub>2</sub>, SFO, ATL)  
Fly(P<sub>1</sub>, SFO, ATL)  
Unload(C<sub>3</sub>, P<sub>2</sub>, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, SFO, ATL)  
Fly(P<sub>3</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, SFO, ATL)  
Fly(P<sub>3</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>3</sub>, ATL, SFO)  
Unload(C<sub>2</sub>, P<sub>1</sub>, JFK)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>1</sub>, JFK, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, SFO, JFK)  
Fly(P<sub>2</sub>, SFO, ATL)  
Load(C<sub>3</sub>, P<sub>2</sub>, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, SFO, JFK)  
Fly(P<sub>3</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, ATL, SFO)  
Unload(C<sub>3</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>1</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, ATL, SFO)  
Load(C<sub>3</sub>, P<sub>1</sub>, JFK)  
Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, SFO, ATL)  
Fly(P<sub>3</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, JFK, ATL)  
Fly(P<sub>3</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, ATL, SFO)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, SFO, ATL)  
Unload(C<sub>1</sub>, P<sub>1</sub>, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, SFO, ATL)  
Fly(P<sub>3</sub>, ATL, JFK)



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

Load(C<sub>3</sub>, P<sub>3</sub>, SFO)  
Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>1</sub>, SFO, ATL)  
Fly(P<sub>3</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>3</sub>, JFK, ATL)  
Load(C<sub>2</sub>, P<sub>3</sub>, ATL)  
Fly(P<sub>3</sub>, ATL, SFO)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, SFO, JFK)  
Fly(P<sub>2</sub>, SFO, JFK)  
Fly(P<sub>1</sub>, JFK, ATL)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, ATL, SFO)  
Load(C<sub>1</sub>, P<sub>3</sub>, JFK)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, SFO, ATL)  
Fly(P<sub>3</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>3</sub>, ATL, SFO)  
Fly(P<sub>2</sub>, SFO, ATL)  
Fly(P<sub>1</sub>, JFK, ATL)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, SFO, ATL)  
Unload(C<sub>2</sub>, P<sub>3</sub>, ATL)  
Fly(P<sub>3</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, SFO, ATL)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, SFO, JFK)  
Fly(P<sub>1</sub>, JFK, ATL)  
Unload(C<sub>3</sub>, P<sub>3</sub>, JFK)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>2</sub>, SFO, ATL)  
Fly(P<sub>1</sub>, SFO, JFK)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>3</sub>, JFK, ATL)  
Fly(P<sub>1</sub>, JFK, ATL)  
Fly(P<sub>3</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Unload(C<sub>1</sub>, P<sub>3</sub>, SFO)  
Fly(P<sub>3</sub>, SFO, ATL)  
Fly(P<sub>1</sub>, SFO, ATL)  
Fly(P<sub>3</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, JFK, ATL)  
Fly(P<sub>3</sub>, JFK, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>3</sub>, ATL, SFO)  
Load(C<sub>3</sub>, P<sub>1</sub>, JFK)  
Fly(P<sub>2</sub>, SFO, ATL)  
Fly(P<sub>1</sub>, JFK, ATL)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, ATL, SFO)

Fly(P3, SFO, ATL)  
Fly(P1, SFO, JFK)  
Load(C2, P3, ATL)  
Fly(P3, ATL, SFO)  
Fly(P2, JFK, ATL)  
Fly(P3, SFO, JFK)  
Fly(P2, ATL, SFO)  
Fly(P1, JFK, ATL)  
Fly(P3, JFK, ATL)  
Fly(P1, ATL, SFO)  
Fly(P3, ATL, SFO)  
Unload(C3, P1, SFO)  
Fly(P2, SFO, ATL)  
Unload(C2, P3, SFO)  
Load(C3, P1, SFO)  
Fly(P2, ATL, JFK)  
Fly(P3, SFO, ATL)  
Fly(P2, JFK, SFO)  
Fly(P3, ATL, JFK)  
Fly(P1, SFO, ATL)  
Fly(P3, JFK, SFO)  
Fly(P1, ATL, JFK)  
Load(C2, P2, 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)  
Unload(C3, P1, ATL)  
Fly(P1, ATL, JFK)  
Fly(P3, ATL, SFO)  
Fly(P2, JFK, ATL)  
Fly(P1, JFK, ATL)  
Fly(P2, ATL, SFO)  
Fly(P1, ATL, SFO)  
Fly(P3, SFO, ATL)  
Fly(P2, SFO, ATL)  
Fly(P3, ATL, JFK)  
Fly(P2, ATL, JFK)  
Load(C1, P1, SFO)  
Fly(P1, SFO, ATL)  
Fly(P3, JFK, ATL)  
Fly(P1, ATL, JFK)  
Fly(P2, JFK, ATL)  
Fly(P3, ATL, SFO)  
Fly(P2, ATL, SFO)  
Fly(P3, SFO, JFK)  
Unload(C2, P2, SFO)  
Fly(P2, SFO, ATL)  
Fly(P3, JFK, ATL)  
Fly(P1, JFK, ATL)  
Fly(P3, ATL, SFO)  
Fly(P2, ATL, SFO)  
Unload(C1, P1, ATL)  
Fly(P1, ATL, 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)  
Load(C3, P2, ATL)  
Fly(P2, ATL, SFO)  
Fly(P3, SFO, ATL)  
Fly(P2, SFO, JFK)  
Fly(P3, ATL, JFK)  
Fly(P1, JFK, ATL)  
Fly(P2, JFK, ATL)  
Fly(P3, JFK, ATL)  
Load(C1, P3, ATL)  
Fly(P2, ATL, SFO)  
Fly(P1, ATL, SFO)  
Fly(P3, ATL, JFK)  
Fly(P2, SFO, ATL)  
Fly(P1, SFO, JFK)  
Fly(P2, ATL, JFK)  
Fly(P1, JFK, ATL)  
Fly(P3, JFK, SFO)  
Fly(P1, ATL, SFO)  
Unload(C3, P2, JFK)  
Fly(P3, SFO, ATL)  
Fly(P1, SFO, ATL)  
Fly(P2, JFK, ATL)  
Fly(P3, ATL, JFK)  
Fly(P2, ATL, SFO)  
Fly(P1, ATL, SFO)  
Unload(C1, P3, JFK)  
Fly(P2, SFO, ATL)  
Fly(P1, SFO, JFK)  
Fly(P2, ATL, JFK)  
Fly(P3, JFK, ATL)  
Fly(P1, JFK, ATL)  
Fly(P3, ATL, SFO)  
Fly(P1, ATL, SFO)  
Load(C3, P2, JFK)  
Fly(P3, SFO, ATL)  
Fly(P2, JFK, ATL)  
Fly(P1, SFO, ATL)  
Fly(P2, ATL, SFO)  
Fly(P3, ATL, SFO)  
Fly(P1, ATL, JFK)  
Fly(P3, SFO, 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: 48.802818862387674

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 GREEDY\_BEST\_FIRST\_GRAPH\_SEARCH WITH H\_1...

Expansions	Goal Tests	New Nodes
998	1000	8982

Plan length: 21 Time elapsed in seconds: 7.331830368458441

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

---

#### 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: 34.453525452228206

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  
1450 1452 13303

Plan length: 9 Time elapsed in seconds: 17.438909029570198  
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

#### SOLVING AIR CARGO PROBLEM 3 USING BREADTH\_FIRST\_SEARCH...

Expansions Goal Tests New Nodes  
14663 18098 129631

Plan length: 12 Time elapsed in seconds: 336.2690922948953  
Load(C1, P1, SFO)  
Load(C2, P2, JFK)  
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)

#### SOLVING AIR CARGO PROBLEM 3 USING DEPTH\_FIRST\_GRAPH\_SEARCH...

Expansions Goal Tests New Nodes  
408 409 3364

Plan length: 392 Time elapsed in seconds: 3.1904954429105397  
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)  
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(C3, P1, JFK)  
Fly(P2, SFO, ORD)  
Fly(P1, JFK, ORD)

Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, ATL, SFO)  
Unload(C<sub>2</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>1</sub>, SFO, ORD)  
Fly(P<sub>2</sub>, JFK, ORD)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, ATL, SFO)  
Load(C<sub>3</sub>, P<sub>1</sub>, JFK)  
Fly(P<sub>2</sub>, SFO, ORD)  
Fly(P<sub>1</sub>, JFK, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, SFO)  
Fly(P<sub>2</sub>, ATL, JFK)  
Unload(C<sub>3</sub>, P<sub>1</sub>, SFO)  
Fly(P<sub>1</sub>, SFO, ORD)  
Fly(P<sub>2</sub>, JFK, ORD)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, ATL, SFO)  
Load(C<sub>3</sub>, P<sub>2</sub>, SFO)  
Fly(P<sub>2</sub>, SFO, ORD)  
Fly(P<sub>1</sub>, JFK, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, SFO)  
Load(C<sub>1</sub>, P<sub>1</sub>, SFO)  
Fly(P<sub>2</sub>, ATL, ORD)  
Fly(P<sub>1</sub>, SFO, ORD)



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

Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Unload(C<sub>2</sub>, P<sub>2</sub>, SFO)  
Fly(P<sub>2</sub>, SFO, ORD)  
Fly(P<sub>1</sub>, SFO, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, JFK)  
Load(C<sub>3</sub>, P<sub>1</sub>, ATL)  
Fly(P<sub>1</sub>, ATL, ORD)  
Fly(P<sub>2</sub>, JFK, ORD)  
Fly(P<sub>1</sub>, ORD, SFO)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, SFO, JFK)  
Fly(P<sub>2</sub>, ATL, SFO)  
Unload(C<sub>3</sub>, P<sub>1</sub>, JFK)  
Fly(P<sub>2</sub>, SFO, ORD)  
Fly(P<sub>1</sub>, JFK, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, ATL, SFO)  
Load(C<sub>3</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>1</sub>, SFO, ORD)  
Fly(P<sub>2</sub>, JFK, ORD)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ORD, SFO)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, SFO, ATL)  
Load(C<sub>1</sub>, P<sub>2</sub>, ATL)

Fly(P<sub>2</sub>, ATL, ORD)  
Fly(P<sub>1</sub>, JFK, ORD)  
Fly(P<sub>2</sub>, ORD, SFO)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, SFO, JFK)  
Fly(P<sub>1</sub>, ATL, SFO)  
Unload(C<sub>3</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>1</sub>, SFO, ORD)  
Fly(P<sub>2</sub>, JFK, ORD)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ORD, SFO)  
Fly(P<sub>1</sub>, ATL, JFK)  
Load(C<sub>3</sub>, P<sub>1</sub>, JFK)  
Fly(P<sub>2</sub>, SFO, ORD)  
Fly(P<sub>1</sub>, JFK, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, ATL, SFO)  
Unload(C<sub>3</sub>, P<sub>1</sub>, SFO)  
Fly(P<sub>1</sub>, SFO, ORD)  
Fly(P<sub>2</sub>, JFK, ORD)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, ATL, SFO)  
Unload(C<sub>1</sub>, P<sub>2</sub>, SFO)  
Fly(P<sub>2</sub>, SFO, ORD)  
Fly(P<sub>1</sub>, JFK, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, JFK)

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

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)  
Load(C4, 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(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(P<sub>1</sub>, JFK, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, ATL, SFO)  
Load(C<sub>3</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>1</sub>, SFO, ORD)  
Fly(P<sub>2</sub>, JFK, ORD)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ATL, JFK)  
Fly(P<sub>2</sub>, ATL, SFO)  
Unload(C<sub>4</sub>, P<sub>2</sub>, SFO)  
Fly(P<sub>2</sub>, SFO, ORD)  
Fly(P<sub>1</sub>, JFK, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, JFK)  
Load(C<sub>2</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>1</sub>, ATL, ORD)  
Fly(P<sub>2</sub>, JFK, ORD)  
Fly(P<sub>1</sub>, ORD, SFO)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, SFO, JFK)  
Fly(P<sub>2</sub>, ATL, SFO)  
Unload(C<sub>3</sub>, P<sub>2</sub>, SFO)  
Fly(P<sub>2</sub>, SFO, ORD)  
Fly(P<sub>1</sub>, JFK, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, ATL, SFO)

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



Fly(P<sub>2</sub>, SFO, JFK)  
Unload(C<sub>4</sub>, P<sub>1</sub>, JFK)  
Fly(P<sub>2</sub>, JFK, ORD)  
Fly(P<sub>1</sub>, JFK, ATL)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ATL, ORD)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ORD, SFO)  
Load(C<sub>2</sub>, P<sub>2</sub>, SFO)  
Fly(P<sub>2</sub>, SFO, ORD)  
Fly(P<sub>1</sub>, SFO, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, ATL, JFK)  
Unload(C<sub>2</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>2</sub>, JFK, ORD)  
Fly(P<sub>1</sub>, JFK, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Load(C<sub>1</sub>, P<sub>2</sub>, SFO)  
Fly(P<sub>2</sub>, SFO, ORD)  
Fly(P<sub>1</sub>, SFO, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, JFK)  
Fly(P<sub>1</sub>, ATL, JFK)  
Unload(C<sub>1</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>2</sub>, JFK, ORD)  
Fly(P<sub>1</sub>, JFK, ORD)

Fly(P<sub>2</sub>, ORD, ATL)  
Load(C<sub>3</sub>, P<sub>1</sub>, ORD)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, ORD)  
Fly(P<sub>1</sub>, ATL, SFO)  
Fly(P<sub>2</sub>, ORD, SFO)  
Fly(P<sub>1</sub>, SFO, JFK)  
Load(C<sub>4</sub>, P<sub>1</sub>, JFK)  
Fly(P<sub>2</sub>, SFO, JFK)  
Fly(P<sub>1</sub>, JFK, ORD)  
Fly(P<sub>2</sub>, JFK, ORD)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ATL, SFO)  
Unload(C<sub>4</sub>, P<sub>1</sub>, SFO)  
Fly(P<sub>2</sub>, ATL, ORD)  
Fly(P<sub>1</sub>, SFO, ORD)  
Fly(P<sub>2</sub>, ORD, SFO)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, SFO, JFK)  
Fly(P<sub>1</sub>, ATL, JFK)  
Load(C<sub>2</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>2</sub>, JFK, ORD)  
Fly(P<sub>1</sub>, JFK, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)  
Fly(P<sub>1</sub>, ORD, ATL)  
Fly(P<sub>2</sub>, ATL, SFO)  
Fly(P<sub>1</sub>, ATL, SFO)  
Unload(C<sub>2</sub>, P<sub>2</sub>, SFO)  
Fly(P<sub>2</sub>, SFO, ORD)  
Fly(P<sub>1</sub>, SFO, ORD)  
Fly(P<sub>2</sub>, ORD, ATL)

Fly(P1, ORD, ATL)

Fly(P2, ATL, JFK)

Fly(P1, ATL, JFK)

Unload(C3, P1, JFK)

---

### SOLVING AIR CARGO PROBLEM 3 USING UNIFORM\_COST\_SEARCH...

Expansions Goal Tests New Nodes

18223 18225 159618

Plan length: 12 Time elapsed in seconds: 180.31168492715437

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(C2, P2, SFO)

Unload(C1, P1, JFK)

---

### SOLVING AIR CARGO PROBLEM 3 USING GREEDY\_BEST\_FIRST\_GRAPH\_SEARCH WITH H\_1...

Expansions Goal Tests New Nodes

5578 5580 49150

Plan length: 22 Time elapsed in seconds: 54.17322964303692

Load(C1, P1, SFO)

Load(C2, P2, JFK)

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

---

### SOLVING AIR CARGO PROBLEM 3 USING ASTAR\_SEARCH WITH H\_1...

Expansions   Goal Tests   New Nodes

18223   18225   159618

Plan length: 12   Time elapsed in seconds: 164.92161645478788

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

Load(C<sub>4</sub>, P<sub>2</sub>, ORD)  
Fly(P<sub>2</sub>, ORD, SFO)  
Fly(P<sub>1</sub>, ATL, JFK)  
Unload(C<sub>4</sub>, P<sub>2</sub>, SFO)  
Unload(C<sub>3</sub>, P<sub>1</sub>, JFK)  
Unload(C<sub>2</sub>, P<sub>2</sub>, SFO)  
Unload(C<sub>1</sub>, P<sub>1</sub>, JFK)

---

### SOLVING AIR CARGO PROBLEM 3 USING ASTAR\_SEARCH WITH H\_IGNORE\_PRECONDITIONS...

Expansions   Goal Tests   New Nodes

5040   5042   44944

Plan length: 12   Time elapsed in seconds: 57.23769514445956

Load(C<sub>2</sub>, P<sub>2</sub>, JFK)  
Fly(P<sub>2</sub>, JFK, ORD)  
Load(C<sub>4</sub>, P<sub>2</sub>, ORD)  
Fly(P<sub>2</sub>, ORD, SFO)  
Unload(C<sub>4</sub>, P<sub>2</sub>, SFO)  
Load(C<sub>1</sub>, P<sub>1</sub>, SFO)  
Fly(P<sub>1</sub>, SFO, ATL)  
Load(C<sub>3</sub>, P<sub>1</sub>, ATL)  
Fly(P<sub>1</sub>, ATL, JFK)  
Unload(C<sub>3</sub>, P<sub>1</sub>, JFK)  
Unload(C<sub>2</sub>, P<sub>2</sub>, SFO)  
Unload(C<sub>1</sub>, P<sub>1</sub>, JFK)