

Based on a combination of the plan length (the number of nodes it took to get to its goal) and the time elapsed using the run_search analysis, overall either a **breadth first search** for uninformed or an **A* search ignoring pre-conditions for heuristics** seemed to be the best type of algorithm to use between the three Air Cargo problems. Based on the table comparing the results from the analysis I've highlighted an overall optimal search for each problem. *Chart 1* lists out the optimal action sequence for each problem

Problem 1	Problem 2	Problem 3
Breadth first search	A* search	A* search
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)	Load(C1, P1, SFO) Fly(P1, SFO, JFK) Unload(C1, P1, JFK) Load(C2, P2, JFK) Fly(P2, JFK, SFO) Unload(C2, P2, SFO) Load(C3, P3, ATL) Fly(P3, ATL, SFO) Unload(C3, P3, SFO)	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)

Chart 1 - Optimal action sequence

Given Air Cargo Problem 1 I found that a breadth first search was the best plan to use. Even though given that a depth first graph search was a 100th of a second faster, the difference in plan lengths made a breadth first search seemed like a more suitable trade off (6 for a breadth first search vs 20 for a depth first graph search). Given a heuristic search I found that an A* search ignoring preconditions was optimal given it's time and plan length of 0.049 seconds and a 6 plan length respectively.

Given Air Cargo Problem 2 & 3 I found that an A* search was the most optimal amongst uninformed and heuristic searches. We find that the plan length of 9 for problem 2 and 12 for problem 3 were amongst the least. Hence weighing the searches based on it's time elapsed helped easily narrow down our choices by selecting the lowest time elapsed. Since our A* search was a heuristic search, I found that a breadth first search was the most optimal for an uninformed search.

Another thing to note was that a depth limited search took over 10 mins to accomplish for Air Cargo Problem 2, and even went over 18 mins for Air Cargo Problem 3 (which was cancelled because it did not finish).

Overall I believed that an A* (heuristic) search seemed to be the most optimal algorithm to use in comparison to the most optimal uninformed algorithm for all three problems. This is due to the fact that we made use of the domain knowledge we implemented. Rather than having the program figure out certain relationships by dishing out extra time and resources, we essentially gave it that information, reducing the overall time elapsed, nodes expanded, etc.

Given an uninformed search algorithm we can see that a the depth limited search seemed to perform the worst out, with problem 2 and 3 exceeding the 10 minute mark for a depth limited search. The depth first graph search produced a plan length that exceeded the hundreds for problem 2 and 3 (619 and 392 respectively)! This was most likely due to the length of the depth of the graph, where our algorithm traveled far out to the end of the graph, accumulating step costs, even though our goal was much further in on the other lateral side of the graph as explained in lesson 8.

		Uninformed			Heuristics		
		breath_first_search (1)	depth_first_graph_search (3)	depth_limited_search (4)	astar_search h_1 (8)	astar_search h_ignore_preconditions (9)	astar_search h_pg_levelsum (10)
Air Cargo Problem 1	Expansion	43	21	101	55	41	11
	Goal Tests	56	22	271	57	43	13
	New Nodes	180	84	414	224	170	50
	Plan length	6	20	50	6	6	6
	Time elapsed (seconds)	0.03657419991	0.02444738999	0.103943635	0.043137067	0.04947484296	0.852624351
Air Cargo Problem 2	Expansion	3343	624	222719	4761	1450	86
	Goal Tests	4609	625	2053741	4763	1452	88
	New Nodes	30509	5602	2054119	43206	13303	841
	Plan length	9	619	50	9	9	9
	Time elapsed (seconds)	9.748253178	5.135306992	1109.160589	13.41678049	4.739876956	144.6950275
Air Cargo Problem 3	Expansion	14663	408	n/a	17873	5034	318
	Goal Tests	18098	409	n/a	17875	5036	320
	New Nodes	129631	3364	n/a	156690	44886	2937
	Plan length	12	392	n/a	12	12	12
	Time elapsed (seconds)	48.31977754	1.972822672	1200.0 +	55.88261528	19.66335386	787.1181064
			Optimal uninformed search				
			Optimal heuristic search				
			Search time elapsed over 10 mins				

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[illegible]

	Uninformed			Heuristics		
	breath_first_search (1)	depth_first_graph_search (3)	depth_limited_search (4)	astar_search h_1 (8)	astar_search h_ignore_preconditions (9)	astar_search h_pg_levelsum (10)
Air Cargo Problem 3	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)	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(P2, ORD, ATL) Fly(P1, ORD, ATL) Fly(P2, ATL, JFK) Fly(P1, 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) Fly(P2, ATL, SFO) Load(C3, P1, JFK) Fly(P2, SFO, ORD) Fly(P1, JFK, ORD) Fly(P2, ORD, ATL) Fly(P1, ORD, SFO) Load(C1, P1, SFO) 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(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)		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) Load(C2, P2, JFK) Fly(P2, JFK, ORD) Load(C4, P2, ORD) Fly(P2, ORD, SFO) Unload(C1, P1, JFK) Fly(P2, ORD, SFO) Unload(C2, P2, SFO) Unload(C3, P1, JFK) Unload(C4, P2, SFO)	Load(C1, P1, SFO) Fly(P1, SFO, ATL) Load(C3, P1, ATL) Unload(C1, P1, JFK) Load(C2, P2, JFK) Fly(P2, JFK, ORD) Load(C4, P2, ORD) Fly(P2, ORD, SFO) Unload(C1, P1, JFK) Fly(P2, ORD, SFO) Unload(C2, P2, SFO) Unload(C3, P1, JFK) Unload(C4, P2, SFO)	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(C1, P1, JFK) Unload(C2, P2, SFO) Unload(C3, P1, JFK) Unload(C4, P2, SFO)