The Basics of Flight Plan Optimization

> **"If you aren't using a performance-based flight planning engine, you are paying too much to fly and working the aircraft harder than it needs to. You cannot afford to overlook the value of optimized flight planning. I have yet to meet someone, whom, if asked 'would you like to save 20 minutes of enroute time and burn less fuel?' has ever answered 'no'."**
>
> Mohammed Husary,
> **UAS** Co-Founder and Executive President

Contents

The **Shortest Distance** Between Two Points

On a one-, two-, or three-dimensional plane, the most optimal route between two points is a straight line. When you have a sphere, like a globe, the intersection of the sphere and a plane that passes through the center point of the sphere is called the great circle distance. When the sphere is flattened, as to display it on a map, the great circle distance typically appears as a curved line, (unless you are viewing a true east-west or north-south trajectory), although it is indeed a straight line.

Using the great circle distance as the baseline for the most direct routes, the great circle route is defined as the shortest distance between any two points on a sphere. By definition, the great circle route is truly the most optimal route between to places; it is the shortest route in terms of time and distance, and is also the route that, if flown, will burn the least amount of fuel. Unfortunately, these direct routes seldom exist in aviation, because of many mitigating factors, including traffic, congestion, terminal procedures, non-modernized avionics, and lack of infrastructure to support these "free-flight" concepts.

In the illustration below (Figure 1), you will see a straight line drawn in brown between the Departure Airport and the Destination Airport. That line, the great circle route, is the shortest distance between the two waypoints. It will be the most optimal route in terms of distance, time, and fuel burn. The grey line is drawn to depict deviations from the direct route. Any deviation from the great circle route will always equate to additional distance, time, and fuel burn.

When flight planning for economics, whether that be for time or cost savings, your goal is typically to find the routes closest to the great circle route while working within the constraints of the system, (like the mitigating factors listed above), and to create a route that is as direct as possible and is acceptable by Air Traffic Control (ATC).

Crews expect to fly the shortest route with the quickest time and the most efficient fuel burn. However, nobody wants to plan a route that is not accepted by ATC. Most pilots fear the "Full Readback Clearance," or FRC, which is when ATC modifies your clearance, in full, undeniably at the most inopportune times. When the engines have started, your flight plan has been entered into the Flight Management System (FMS), and the passengers are on board, nobody wants to call ATC for a clearance to be met with the dreaded words "standby for updated clearance." The crew is then forced to copy and initialize a new route, which will most likely have an impact on aircraft performance, time, fuel burn, and procedures. This FRC, typically relayed quickly over the radio, supersedes all of the planning you have done thus far, and increases the propensity for errors exponentially.

As a flight planning provider, our goal is to make sure that you get the most efficient, or optimal route, which is met by the reassuring words "cleared as filed."

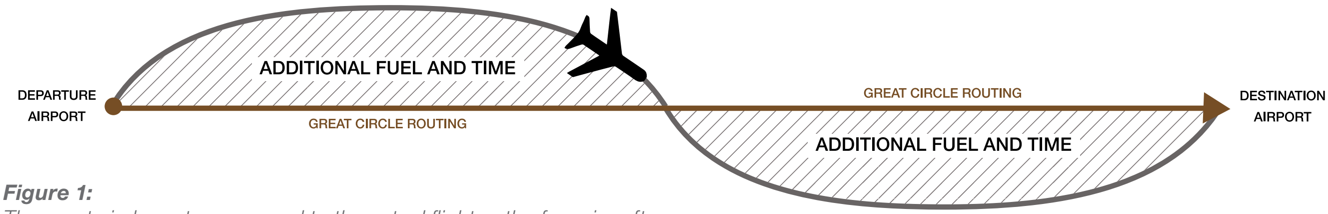

Figure 1:
The great circle route compared to the actual flight path of an aircraft.

Multiple Types of **Optimization**

In terms of flight planning optimization, most of the time we speak of the scenario presented above, which is to find the route with the fastest time and least amount of fuel burned between departure and destination. However, other optimization methods do exist, and the most common are in Figure 2.

Not all optimization types are right for all flights. If there is an important meeting that must not be missed, the flight department may lean towards time optimization instead of fuel burn, economics, or ride quality. On the other side, nervous travelers may opt for the best ride quality, the route with the least amount of bumps, regardless if that route takes 30 minutes longer and burns more fuel.

Time	Optimizing a flight plan to achieve the shortest enroute time possible, regardless of the impact on fuel burn, economics, or ride quality.
Fuel Burn	Optimizing a flight plan to achieve the lowest possible fuel burn, regardless of the impact on time, economics, or ride quality.
Economic	Optimizing a flight plan to achieve the lowest monetary cost of operation, in terms of direct operating costs (DOCs), variable costs, enroute charges, terminal charges, and other ancillary charges, such as overflight permits or government fees. This method involves some degree of fuel optimization as well, since fuel burn is directly correlated with the economics of the aircraft's operating costs. This method does not consider time optimization a critical trait; the only critical item is the effect on the bottom line.
Ride Quality	Optimizing a flight plan with regards to comfort of flight, most notably the strict avoidance of turbulence, avoiding unnecessary turns or maneuvers, and steep takeoff and landing transitions. This method does not consider time, fuel burn, or economic optimization.

Figure 2:
Optimization methods.

However, it is genuinely agreed that most passengers prefer a healthy mix of all four of the optimization types listed above. Pilots and passengers alike typically want to get to their destination in the shortest amount time and burning the least amount of fuel while selecting a financially prudent route that is generally free of turbulence.

Therefore, flight planning in the general aviation market space is normally best served by combining the optimization methods, weighing some optimization types heavier in the planning algorithms.

Typically Speaking:

Fuel-burn optimization is the variable that is paramount. Fuel is the single most expensive factor when dealing with aviation; it accounts for an estimated 40 percent of all flight department budgets. Finding routes that optimize fuel burns (i.e., burning less fuel) becomes the most important of the optimization factors.

Time optimization is the second most important variable and is very close to fuel burn optimization in terms of weight and importance. Finding the fastest route, on both a horizontal and vertical plane, is incredibly important, especially to passengers.

Ride-quality optimization carries significantly less weight than the optimization for both fuel and time. Most pilots and passengers want a route that is relatively comfortable, but most are not willing to increase fuel burn and travel time to achieve a smoother flight, unless it is a significant and dramatic difference in quality and comfort.

Listing economic optimization as the least important is a red herring because fuel burn optimization and time optimization are directly correlated to economics, so economic optimization is occurring at the highest levels in the weighted algorithm. Other economic optimizations, such as overflight permits, navigation fees, special-use fees, etc., however, will be weighted heavier as flight planning algorithms continue to improve and expand.

Area Optimization vs. **Flight-Level** Optimization

Optimization is a multi-dimensional occurrence. The most important dimensions are the area navigation (horizontal plane) and the flight-level (altitude or vertical plane) optimization, shown in Figure 3. Simply stated, a performance-based flight planning provider is a provider that analyzes the area between two points, and creates the most fuel- and time-efficient route of flight between those two points. This may include using the information known about the horizontal plane and the vertical plane, aircraft performance characteristics, manufacturer's performance data, winds, temperatures, weather, aircraft and crew capabilities, aircraft restrictions, airspace restrictions, and other known data. A performance-based flight planning provider creates dynamic routes based on complex algorithms in order to find the shortest and most prudent route.

Providers who do not use performance-based planning are only using anecdotal information and not providing highly accurate computations. This will be discussed later in this paper.

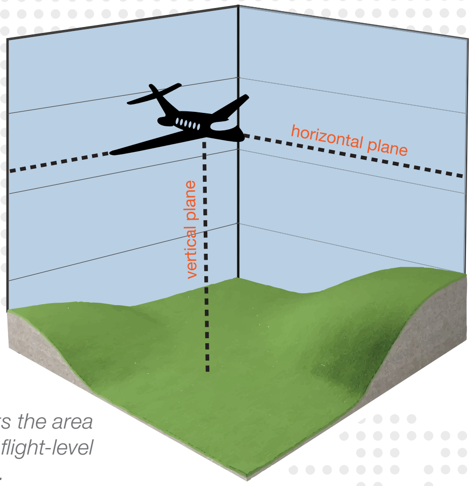

Figure 3:
This diagram depicts the area navigation and the flight-level optimization planes.

The **Phases** of Flight

To effectively optimize a flight plan, the airborne portion of the route is divided into the following area segments, defined and illustrated below in Figures 4-6, and different methods are applied to each.

SEGMENT 1:
DEPARTURE TERMINAL AREA

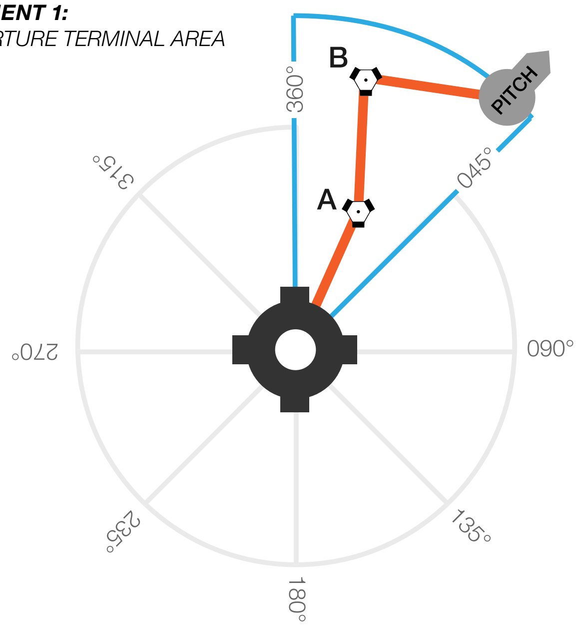

Figure 4:
Diagram of the terminal area segment for the departure airport.

Segment 1 in Figure 4 refers to the terminal area around the departure airport, including, but not limited to the standard departure procedures. It is referred to as the Departure Terminal Area, and is defined as the area from the runway to the PITCH point.

Most airports have common or standard procedures for traffic that is dependent on the direction of the departure. For the purposes of illustration, the departure airport on the left is divided into 45-degree segments. Each of these slices are coded with the most common or likely routes. For example, departures to the NNE are typically given a clearance to Waypoint A then to Waypoint B.

Because the routing inside of the terminal area is controlled by ATC, it is not prudent to optimize in this area (however, most of these common routes are fairly optimal). Most attempts to plan direct routes using great circle lines in this area will likely result in a FRC or the denial of the flight plan.

Each airport has common routes (Common Route Segment) included in the flight planning engine, and occasionally those routes will change over time. If there is an airport without any common routes, the flight planning engine will optimize this segment based on the runway or runways used and the direction of flight.

SEGMENT 2: *ENROUTE*

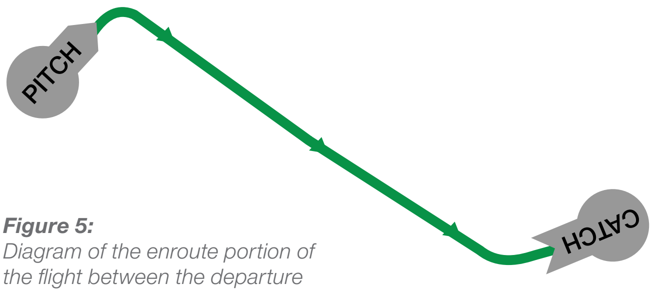

Figure 5:
Diagram of the enroute portion of the flight between the departure terminal area and the arrival terminal area.

Segment 2 in Figure 5 refers to the enroute portion of the flight, which is the area between the departure terminal area and the arrival terminal area. In terms of optimization, it is defined as the segment of the route between the PITCH point and the CATCH point.

For clarity, the PITCH point is the waypoint where optimization begins and the CATCH point is the waypoint where the optimization terminates in favor of the common route segments. It can be easily remembered as the route is "pitched" out of the departure area into the optimized sector, and then "caught" by the arrival area.

This area in between, the enroute segment, is where the random routings can occur, and where the most optimal routes can be achieved. The algorithms used to optimize this segment of the flight are described later in this paper, but the goal of optimization in this area is to get as close to a great circle line as possible while maintaining a route that is acceptable to ATC.

Segment 3 in Figure 6 refers to the terminal area around the arrival airport, including, but not limited to the standard arrival procedures. It is referred to as the arrival terminal area and is defined as the area from CATCH point to the runway.

As for departures, most airports have common or standard procedures for traffic that is dependent on the direction of the arrival. For the purposes of illustration, the arrival airport on the left is again divided into 45-degree segments. Each of these slices are coded with the most common or likely routes. For example, arrivals from the SWW are typically given a clearance to Waypoint C, then to Waypoint D, and then to land.

Because the routing inside of the terminal area is controlled by ATC, it is not prudent to optimize in these areas. Most attempts to plan direct routes using great circle lines will likely result in the in-flight re-assignment of new arrival procedures.

SEGMENT 3:
ARRIVAL TERMINAL AREA

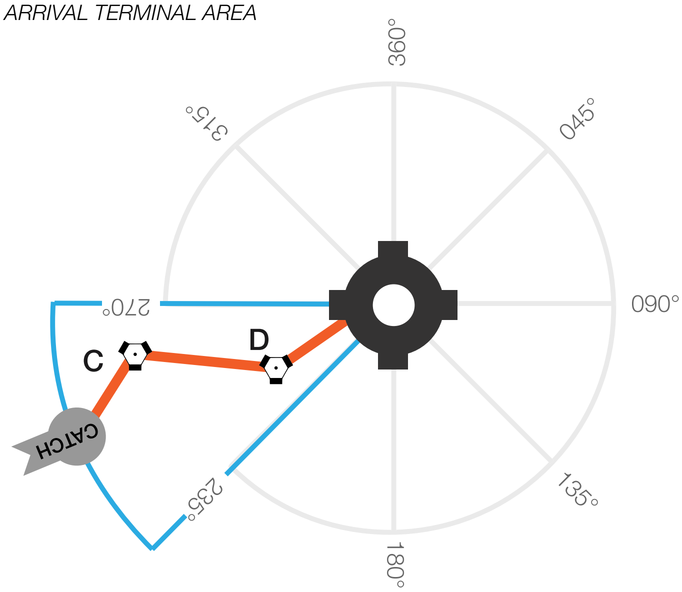

Figure 6:
Diagram of the terminal area segment for the arrival airport.

Each airport has common routes (common route segment) included in the flight planning engine, and occasionally those routes will change over time. If there is an airport without any common routes, the flight planning engine will optimize this segment based on the runway or runways used and the direction of flight.

Area Navigation **(Horizontal Plane)** Optimization

Understanding that the three phases are treated differently, let's focus on the horizontal plane (i.e., picking the route). When each of these phases is laid together chronologically (Figure 7), you will easily see that the enroute portion of the flight (between the PITCH and CATCH points) is where the majority of in-flight optimization occurs.

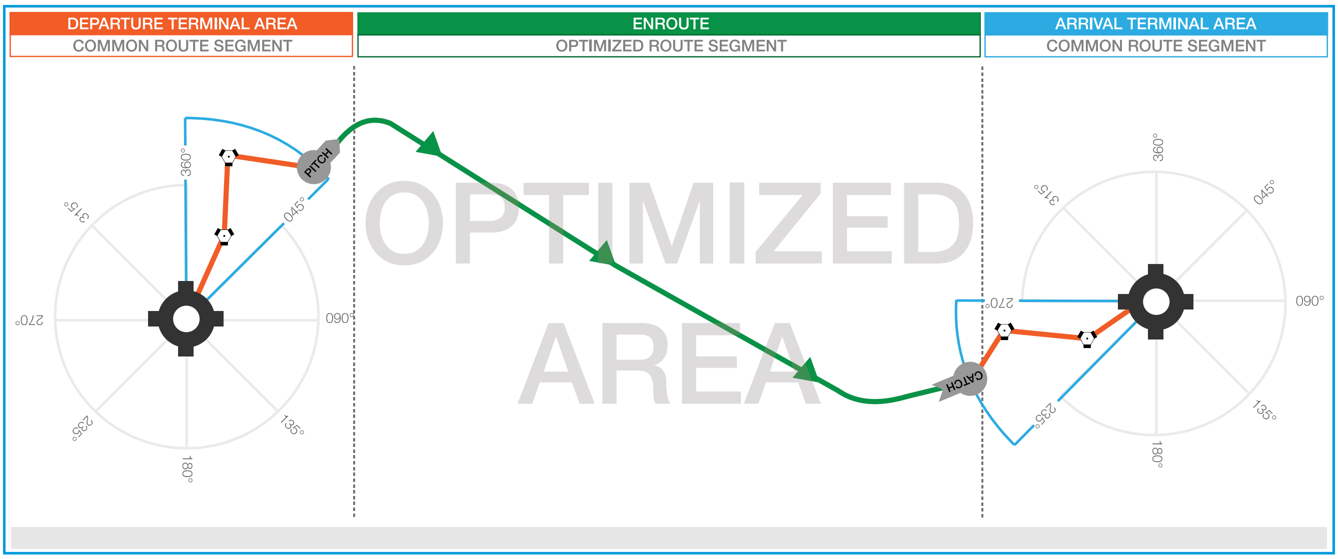

Figure 7:
Overhead view showing all three segments connected, as they would be in an actual flight.

As discussed previously, the most optimal route between two points, such as Airport A and Airport B, is the great circle route, and any deviation from this direct line equates to additional fuel burned and increased flight time. (See Figure 8.).

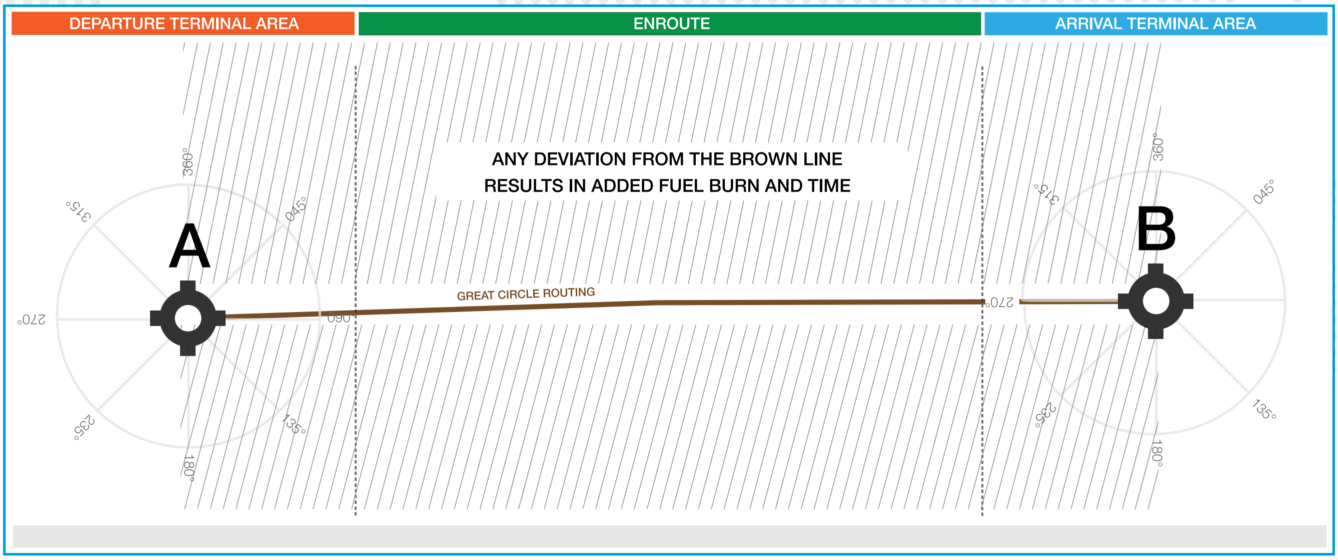

Figure 8:
Diagram illustrating the great circle route between airports A and B.

However, ATC is not going to give you this route the overwhelming majority of the time. In fact, they will most likely put you on published or ATC routes, which are non-dynamic waypoints and require point-to-point navigation. An example of airway routing is shown here, in red (Figure 9). The hatched area is meant to depict inefficiency in both time and money.

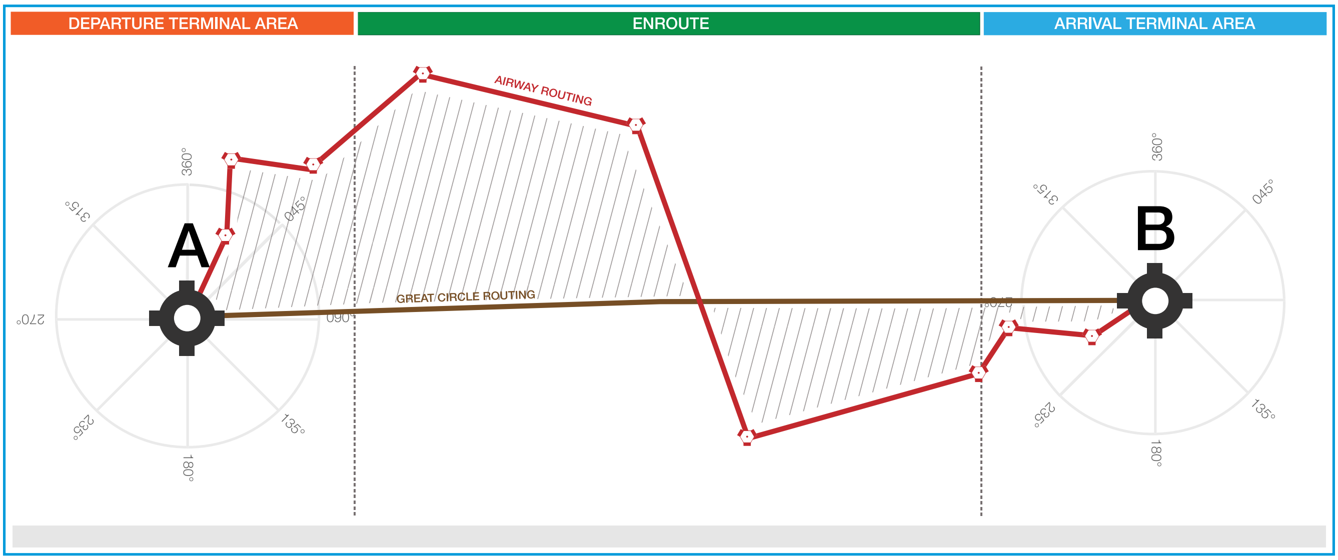

Figure 9:
Diagram shows a typical published or ATC airway routing.

The more efficient way to optimize for time and fuel savings, as well as retaining an acceptable ATC flight plan, is to use common routes in both of the terminal areas and modify the enroute portion of the trip. You may be stuck flying the non-optimal routes in the terminal areas, but the enroute portion is an area where significant time and fuel savings can be had. In the illustration below (Figure 10), note the time and fuel savings in between the airway routing and the optimized routing (shown in green).

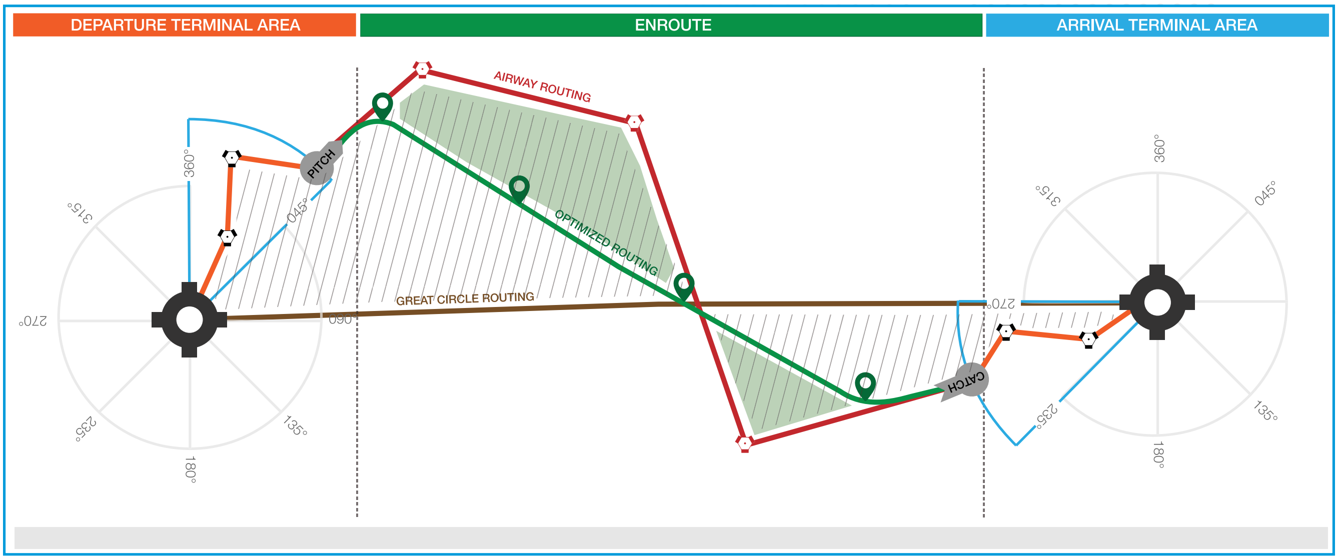

Figure 10:
Diagram shows an optimized airway routing with time and fuel savings.

Flight-Level **(Vertical Plane)** Optimization

After the preferred horizontal route is determined, the axis is rotated to allow the planning algorithm to determine the best altitude for the plan. Unlike horizontal optimization, the aircraft attempts to find the most efficient altitude in all sectors (departure, enroute, and arrival), based on winds, temperatures, and aircraft performance capabilities. Many times, if left undefined, the plan will optimize the airplane to its most efficient fuel flow altitude. If the aircraft cannot climb directly to that altitude, most flight planning engines will insert step climbs into the route to maximize efficiency and to get the aircraft to the optimal altitude as quickly as possible.

Also, the flight plan may step to lower altitudes during the flight as well if the winds are more favorable at the lower level. Either way, the performance calculator tries to get the aircraft to the top-of-climb (TOC) waypoint as fast and efficiently as possible. The plan will continue to top-of-descent (TOD), where it will optimize the transition to the descent profile (see Figure 11).

Altitude planning can affect time and fuel performance as much as horizontal optimization.

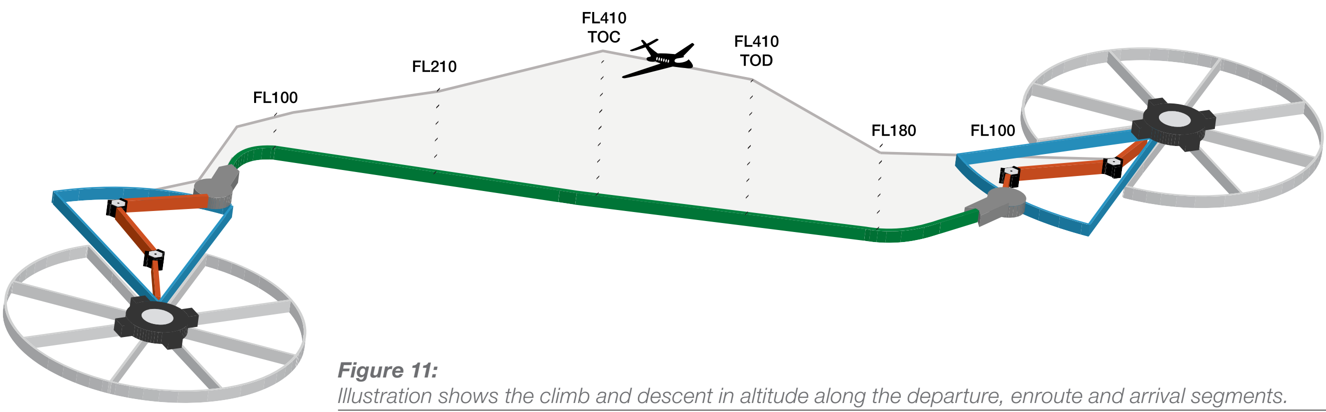

Figure 11:
Illustration shows the climb and descent in altitude along the departure, enroute and arrival segments.

The "Free" Paradox and the **Value of Optimization**

Typically, flight planning systems with true optimization capabilities are priced at a premium. It is easy to dismiss them in favor of a multitude of systems available for free. It's hard to compete with free.

However, the old adage, "you get what you pay for" holds true and you actually wind up paying significantly more in the long run when you use a free system. Saving a few hundred dollars a month by using a free system will not begin to compare to the thousands of dollars you will lose by not taking advantage of a true performance-based flight planning solution.

The largest difference between performance-based flight planning systems and most of the free tools is the free tools aren't actually doing any flight planning at all. They take the most recently cleared flight routes (optimized or not) and present them as selections for you. When you select the route, they take the distance and divide it by the average airspeed you specify. They don't take into account any of the manufacturer's performance data, including takeoff, climb, enroute, descent, or landing data, nor do they typically make adjustments for altitudes, temperatures, winds, and non-standard International Standard Atmosphere (ISA) data. Non-optimized routes and anecdotal speed and time calculations is a recipe for failure.

A quick overview of the main differences between free and performance-based flight planning providers:

Comparison Chart	Free Flight Plan Providers	Performance-Based Flight Plan Providers
Optimized Flight Plans	No optimization	Optimization on winds, temperatures, turbulence, and other economics
Available Regions	Typically the U.S., the Caribbean, and regions where historical routes are published	Worldwide
Route Catalog	None. Routes are typically derived by using data on historical flights	Worldwide, dynamic routing updated every 28 days; does not rely on historical data for calculations
Time Calculations	Typically, distance divided by average speed	Time calculations based on aircraft performance data, including climb, cruise, and descent data, winds and temperature data, forecast data, terminal constraints, enroute airspace constraints, restrictions, closures, and other events
Fuel Calculations	Typically, gallons per hour multiplied by hours flown	Fuel calculations based on all aircraft performance data, including climb, cruise, and descent data, winds and temperature data, and forecast data.
Flight-Level Optimization	Typically none; flight plan computations don't take vertical optimization into account; altitudes are filed as preferences only	Altitude calculations based on aircraft performance data, including climb, cruise, and descent data, winds and temperature data, forecast data, terminal constraints, enroute airspace constraints, restrictions, closures, and other events; step-climb optimization for various flight and performance segments
Aviation Support Team	24/7 support not typical; advanced aviation support not typical	Typically 24/7 support from flight planning experts, system experts, and flight dispatchers with intimate knowledge of your missions
Revenue Stream	Typically ad-based or ad hoc charges for advanced features	Subscriptions, no ads

The best way to show the value of a performance-based flight planning provider with access to flight plan optimization is to run live comparisons. Multiple case studies were conducted and the results were astonishing.

The graphs below (Figures 12 and 13) show the results of a number of flight plans run on a Gulfstream IV (GLF4) aircraft between the same city pairs, over the same time period.

Case Study

GULFSTREAM IV

Fuel & Cost Savings

HOURS FLOWN	FUEL USED NON-OPTIMIZED	FUEL USED OPTIMIZED	SAVINGS (POUNDS)	SAVINGS (GALLONS)	SAVINGS (US DOLLARS)	SAVINGS (USD PER HOUR)
300	893,709 lb	852,921 lb	40,788 lb	6,087 gal	$12,113	$40.44
400	1,191,612 lb	1,137,228 lb	54,384 lb	8,117 gal	$16,152	$40.38
500	1,489,515 lb	1,421,535 lb	67,980 lb	10,146 gal	$20,190	$40.38

Figure 12:
Case study demonstrating fuel savings in gallons and U.S. dollars.

NOTES:
UAS flightevolution™ *vs. FltPlan.com / 30 April 2016 / Fuel = 6.7 lb per USG / Average Fuel Price $1.99 per gallon*

Time & Cost Savings

HOURS FLOWN	AVERAGE TIME SAVED	ESTIMATED FLIGHT TIME OF THE SAME ROUTES WHEN USING OPTIMIZED FLIGHT PLANS	SAVINGS (HOURS)	SAVINGS (US DOLLARS)
300	1 min 18 sec average time savings per hour when using optimized routes	293.5 hours	6.5 hours	$27,443
400		391.3 hours	8.7 hours	$36,731
500		489.2 hours	10.8 hours	$45,597

Figure 13:
Case study demonstrating time and U.S. dollars saved.

NOTES: **UAS flight**evolution™ *vs. Fltplan.com/30 April 2016 / Gulfstream G-IV hourly rate $4,222 per hour*

Over the course of 400 hours, the GLF4 optimized flight plans burned $16,152.00 USD less fuel, resulting in a reduction of $40.00-plus USD per hour in fuel alone. For the same number of hours flown, the aircraft also shaved an approximate 1 minute, 18 seconds off each hour of flight, saving 8.7 hours of total flying time and resulting in $36,731.00 USD in direct operating cost savings. Assuming a price tag of $5,000.00 USD per year for the flight planning engine, the Gulfstream operator recouped his investment in the 38th hour of flight.

Similar studies were run for a King Air 350, a Citation XLS, and a Boeing Business Jet (BBJ) 737. Using the same $5,000.00 USD price assumption, the King Air recouped their investment in the 57th hour, the Citation in its 44th hour, and the BBJ in its 26th hour.

The flight departments who used optimized flight planning saved on average $48,019.00 USD in direct operating costs,including fuel.

> **"At UAS, we believe in utilizing our international expertise to eliminate client pain points. We're currently developing some of the most advanced operational tools on the market, exhausting all possibilities to deliver the most customized and responsive solutions to pilots' unique requirements, no matter how complex."**
>
> Jay Ammar Husary,
> **UAS** Executive Vice-President

Conclusion

> **The most optimal route between two locations is a straight line. It is our job to get you as close to that straight line as possible, while also getting you an approved flight plan."**
>
> Ryan Frankhouser,
> **UAS** Regional Director, Americas

Flight planning optimization is more than just a good idea. Based on the potential savings in time and costs alone, it is not a luxury either. Optimization makes sound business sense for everyone involved: The aircraft owner, the operator, the pilots, passengers, and crew.

Performance-based flight planning providers deliver superior products over free providers and offer added value continually through reliable, accurate, quality flight plans that are tailored to the operator's unique needs and priorities. They also provide the 24/7 support and personalized service that provide genuine peace of mind when the aircraft is loaded and ready to take off.

UAS International Trip Support has extensive experience with flight planning optimization and can help with performance-based flight planning for any destination in the world. For information about **UAS**evolution™, our cutting-edge suite of online and mobile devices for flight, trip and fuel planning, visit www.uas.aero/evolution.

Frequently Asked **Questions**

Q Most performance-based flight plan providers all use the same database and update cycle. What makes one provider better than another?

A There are a number of answers to this question, like, finding an easy-to-use solution, finding a provider who genuinely cares about your flight department, the number of advanced features available, integrations available, etc. If we are talking strictly about flight plan optimization, I offer the following: We all use GPS and navigation systems, apps, and tools for a number of day-to-day activities, and each one of these use the same roads to plan on. We tend to gravitate toward the solution that is most robust and offers the most value with their user experience. For example, you would most likely choose to use the application that has up-to-date traffic data, lane closure information, weather data, road hazards, and alternate routes. It's not about the roads (or the airways in this case) that are the discriminating factors. The value comes from what the application provides in terms of accuracy, speed, efficiency, user experience, and how it makes your life easier and more enjoyable. The same is true when you choose a flight planning provider.

Q How often are optimized routes granted by ATC?

A In a six-month study of optimized routes filed within the Americas and over the oceans, over 85 percent were accepted by ATC without amendment or change. Full route acceptance numbers go down internationally, especially in airway slot controlled regions, but optimization was still accepted in nearly 73 percent of the flight plans. Optimized plans are a precursor to the next evolution of worldwide airspace systems and procedures, and their acceptance rate is higher than previously thought. On many occasions during the study, only one or two waypoints were changed prior to acceptance, which does not reflect in the numbers herein.

Q Aren't the routes provided to me as "recently cleared" or "frequently cleared" by my flight plan provider optimized?

A No. Those routes are what have been previously filed, period. Some of those routes may be optimized routes, but most of those routes are "canned" or ATC routes that are used over and over again. If your flight plan provider displays the aircraft type that recently flew those routes, chances are the aircraft type is a commercial airliner, and those routes do not always translate well into the general aviation space. In addition, those routes are typically older and the flight plans aren't optimized for altitude, just area navigation.

Q Any other advice you would give when comparing flight plan providers?

A Find a flight plan provider who takes your feedback seriously and is committed to constantly evolving their products. Take advice from operators like yourself and ask for references. Ask about the pros and cons of the system. On a technical level, make sure that your flight plan provider can uplink to your datalink provider, computes performance-based flight plans, complies with all MEAs and safety altitudes, and offers the full feature set you are looking for, like online and offline flight planning, mobile applications, etc. One of the most often overlooked features is access to a 24/7 help desk that can provide advanced aviation support, flight planning help, and technical assistance. Find a provider who offers an enjoyable user experience and is constantly innovating.

UAS

International Trip Support

About **UAS** International Trip Support

UAS International Trip Support is a leading global trip support solutions provider, trusted by heads of state, VVIPs, Fortune 500 companies, and business jet operators worldwide. With a global network that includes continental headquarters in Houston, Johannesburg, Hong Kong, and Dubai, regional offices in Lagos, Nairobi, Beijing, and New Delhi, and station managers in 23 global locations, we deliver consistent operational excellence and the UAS standard of quality, anywhere in the world. Our international network ensures unrivalled connectivity, and we pride ourselves on the uniquely customized solutions we provide for our clients' every aviation requirement. Our experienced international and multilingual industry experts provide 24/7 support, executive travel, and air charter services. UAS Trip Support Services include flight planning, weather services, overflight and landing permits, ground handling, catering, fuel, and crew services. UAS Executive Travel takes care of Hotel Bookings, VIP Transportation, Airport Meet and Assist, Air Ticketing, Visa Assistance, Security Services, and Concierge Services. Air Charter Services provide for your every requirements regarding VVIP Jets, Business Jets, Air Ambulance, Helicopter and Commercial Aircraft.

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