A PROPOSED TRANSPORTATION SYSTEM FOR ROADABLE AIRCRAFT

JEFFREY W. BUCKHOLZ, PHD, PE, PTOE

Buckholz Traffic
3585 Kori Road
Jacksonville, Florida 32257
(904) 886-2171
jwbuckholz@aol.com

ABSTRACT

Production of a cost competitive roadable aircraft (roadcraft?) that meets all pertinent safety and performance standards, both on the ground side and the air side is eminent. Unfortunately, our highway system and air traffic control system are not currently coordinated in a manner conducive to roadable aircraft operation. The use of roadable aircraft would become much more attractive if some sort of rational transportation system existed for accommodating them. The purpose of this paper is to make an initial stab at proposing such a system.

The existing interstate highway system offers a widespread, comprehensive public-owned ground skeleton over which low level air corridors for roadable aircraft could be oriented. In addition, the interstate system offers a substantial amount of existing public right-of-way along which adjacent runways could be constructed; runways with direct ramp connections to the interstate highway for quick and efficient air-to-road and road-to-air transition. Advanced GPS technology located within each roadable aircraft would be used to guide the vehicle along the desired path. The various air routes would be displayed on each roadable aircraft's GPS system as a set of lateral boundaries, allowing for straightforward navigation. The key to safe operation will be the automated closure of air routes when weather conditions become unfavorable and, as vehicle control systems become more sophisticated, elimination of human intervention in favor of automated vehicle control to the maximum extent possible.

Introduction

Cars that can fly. The idea has actually been around for quite awhile with the first roadable aircraft taking flight back in 1937 [1]. However, for a variety of reasons ranging from cost to safety, the idea has never really "taken-off". Production of a cost competitive roadable aircraft that meets all pertinent safety and performance standards, both on the ground and in the air, has not occurred. That will soon change however as a few MIT-trained engineers have flight tested (and begun taking deposits on) what they are calling the Transition roadable aircraft. The Terrafugia web site [2] provides the following information on the Transition:

Price: $194,000

Occupants: 2

Fuel: Premium gasoline

Maximum roadway speed: 65 mph

Roadway fuel usage: 30 mpg

Cruise speed: 115 mph (100 knots)

Air fuel usage: 5 gph

Fuel capacity: 20 gallons

Take-off distance (over 50-foot obstacle): 1700 feet

Time to deploy/stow wings: 15 seconds

The following information on the vehicle was obtained via email from Terrafugia:

Avionics: Glass panel display is anticipated

Maximum crosswind for take-off: unknown at this time (but probably comparable to similar low wing aircraft)

Unfortunately, the currently disparate roadway system and air traffic control system are not particularly conducive to roadable aircraft operation. You can't just pull out of your driveway, take-off on the neighborhood street and land in your office parking lot. With the current system one basically has to drive to the nearest general aviation airport, convince someone to give you access to the airfield (unless it is an unsecured airfield or you have made previous arrangements), fly to the airport nearest your destination, convince someone to let you back out of the secured airport environment, and then drive to your destination. Since neither general aviation airports or publically available airstrips are located right around the corner, the use of a roadable aircraft ends up making little sense from either an economic or time-saving perspective unless the origin and destination of the trip are fairly far apart - or unless there is some physical restriction that only an airplane could overcome, such as a body of water, wilderness area, or mountain range.

The use of roadable aircraft would become much more attractive if some sort of rational transportation system existed for accommodating them. The purpose of this paper is to make an initial stab at proposing such a system. I know quite a bit about the roadway side of the equation because I am a qualified traffic engineer of over 30 years experience. My knowledge on the air side is less complete. I recently completed my private pilot certification and am still learning the various nuances associated with US airspace. However, I think I have learned enough to propose a system that should be workable. At the very least, it will serve as a good straw man for others (including myself) to comment on in the future, and undoubtedly improve.

Basic System Operation

Safety is the primary goal of any transportation system and a system for handling roadable aircraft is no different. Amateur pilots flying around at low altitudes over neighborhoods, school yards, and hospitals would obviously cause a certain level of consternation in the general public. Having aircraft flying around in all directions at relatively low levels could also result in frequent violations of the US airspace system. A reasonable way to address this safety issue is to restrict roadable aircraft to predefined low altitude corridors where pilots of "regular" aircraft could expect them. The existing interstate highway system offers a widespread, comprehensive, public-owned ground skeleton over which such air corridors could be oriented. If a roadable aircraft were to experience an engine failure or other malfunction, an emergency landing on an interstate highway road surface or in an interstate highway median would be much less problematic than an emergency landing in a neighborhood or commercial district. The interstate system is also an easy landmark for pilots to follow, reducing the probability of lost aircraft.

In addition, the interstate system offers a substantial amount of existing public right-of-way along which adjacent runways could be constructed; runways with direct ramp connections to the interstate highway for quick and efficient air-to-road and road-to-air transition. Figure 1 provides a proposed layout for a set of interstate runways as well as a means for handling air traffic in the area of the runway. Non-landing traffic would continue above the interstate travelway while landing traffic would descend, proceeding directly to the runway or making left traffic to land, depending on wind direction. Likewise, take-offs would either be made directly toward the desired direction of travel or would be made opposite the direction of travel with a left traffic pattern used to reach the interstate travelway.

The runway access gate would only provide access to roadable aircraft equipped with a transponder issued by the FAA. This transponder could also be used to charge the aircraft for each takeoff or landing by encoding a monetary charge every time the roadable aircraft activated either the entry or departure gate. These funds could be used to help maintain the system. The access gate would also restrict entry to the runway when the runway was being used by another roadable aircraft, thus avoiding runway incursions. The access gate would be automated and would not open until either the departure gate opened to let out a landing aircraft or an aircraft taking off became airborne.

Ideally, runways would be situated at major freeway-to-freeway interchanges so that a set of perpendicular runways could be provided (see Figure 2). This would provide for system operation over a wide range of wind directions. All runways in the system could be used by "regular" general aviation aircraft in the event of an emergency. Runway locations would be spaced at reasonable intervals, such as every 60 statute miles in populated areas and every 120 statute miles in more remote areas.

Restricting roadable aircraft to the airspace over the interstate highway system would result in needlessly circuitous routes in some areas where interstate coverage is sparse, such as in the plains states. In these areas, major non-interstate roadways (preferably multi-lane grade separated, although not necessarily so) could also be incorporated into the system. In addition, as the system becomes fully developed, it would be reasonable to introduce what could be called "interstate air routes" to supplement the existing highway system. These interstate air routes would not follow any specific roadway but would instead form direct 4 mile wide air links between existing ground routes. They would generally be oriented over sparsely populated areas and would be particularly valuable where physical obstructions, such as bodies of water or mountains, have precluded the development of a corresponding highway route.

The roadable aircraft air routes would follow the numbering of the roadway over which they were oriented, with a cardinal direction added at the end and the letter A (for Aircraft) added at the beginning. For example, roadable aircraft flying above northbound Interstate 75 would be on route A75N while roadable aircraft flying eastbound above US 41 would be on route A41E. Pure interstate air routes (those not located over a highway) could be labeled using state abbreviations, such as GA1N or GA1S for Georgia 1 Northbound and Georgia 1 Southbound, with odd numbers used for north-south routes and even numbers used for east-west routes as is done with the interstate highway system. The number 1 would be used for the easternmost north-south route and the number 2 would be used for the northernmost east-west route, with the numbering incrementing by two's until the last route is reached. For example, if there were four east-west air interstate routes in Georgia, the northernmost one would be labeled GA2E and GA2W and the southernmost one would be labeled GA8E and GA8W. If an interstate air route crossed state lines, then the route designation would be given using the state in which the majority of the route was located.

Interstate highways often do not travel along a straight path, but curve about to miss development or topographic features. It would be rather inefficient to have the roadable aircraft routes bend about in a similar manner. Consequently, as is demonstrated in Figure 3, the roadable aircraft corridor would sometimes deviate from its parent interstate route for a short distance to make the trip more direct. These segments of the trip are referred to as independent segments. Advanced GPS technology located within each roadable aircraft would be used to guide the vehicle along the desired path, including independent segments and interstate air routes. The various air routes would be displayed on each roadable aircraft's GPS system as a set of lateral boundaries, allowing for straightforward navigation.

Altitude and Spacing

To minimize the chance of mid air collisions, roadable aircraft would be required to follow specified altitude and spacing criteria. The following altitudes (+/- 100 feet) are proposed for use. They are based on the nominal direction of the route being followed: Northbound - 1700 feet AGL, Southbound - 2000 feet AGL, Eastbound - 2600 feet AGL, and Westbound - 2900 feet AGL. The altitudes are purposely low in an attempt to reduce climb and descend times and to minimize interference with "regular" general aviation airplanes. While following the interstate, pilots of roadable aircraft would be required to "keep to the right" of the interstate centerline in a further effort to avoid potential conflicts with roadable aircraft heading in the opposite direction. Roadable aircraft would also be required to stay within 1 mile laterally of the interstate.

As an example, roadable aircraft travelling above southbound I-75 would maintain a cruise altitude of between 1900 feet and 2100 feet. In general, the altitude of roadable aircraft during normal cruise flight would vary between 1600 feet and 3000 feet AGL depending on the nominal direction of the route being overflow. The minimum altitude of 1600 feet is established to provide sufficient clearance over ground obstructions such as radio towers.

A desired nominal spacing of 4 miles between roadable aircraft flying along the same directional route (such as A95S) would be established.   At a typical cruise speed of 115 miles/hour (100 knots), this results in a nominal time between aircraft of just over 2 minutes. Modern GPS technology would be required on all roadable aircraft to ensure that the desired spacing is maintained. A 4 mile spacing would allow other roadable aircraft to merge in without getting vehicles too close together. Roadable aircraft would enter a particular route either at a runway location along that route or at a point where another air route is crossed.

Unlike automobiles, air merges would be made vertically. The advanced GPS unit within each roadable aircraft would be used to help effectuate the merge. A minimum 1 mile spacing immediately after the merge would be required, with vehicles repositioned to a 2 mile spacing as soon as practicable. The most demanding cross-route vertical merge would be a northbound-to-westbound merge with a 1200 foot climb required (from 1700 feet to 2900 feet AGL). Using a standard 500 feet/minute climb rate, the time to merge would be just under 2-1/2 minutes. Assuming a corresponding horizontal speed during climb of 90 statute miles/hour (78 knots), it would require less than 4 statute miles to complete the merge.

The most demanding take-off merge would be a take-off to intersect an eastbound route with a 2900 foot climb required. Again using a standard 500 feet/minute climb rate, the time to reach the desired altitude would be just under 6 minutes. At a climbing speed of 90 statute miles/hour, less than 9 statute miles would be required to complete the merge. Likewise, a take-off to intersect a southbound route would take 4 minutes and 6 statute miles to reach the required 2000 foot altitude.

It would be mandated that all “vertical merges”, both route-to-route merges and take-off merges, be completed within a pre-set time limit, such as 7 minutes, to keep roadable aircraft at their desired altitudes.

Assuming that merges eventually fill 50% of the available spaces between aircraft, the resulting average system-wide spacing between roadable aircraft would become 3 miles, or a density of 0.33 vehicles/statute mile. At a cruise speed of 115 statute miles/hour (100 knots) this produces a directional capacity of about 38 vehicles/hour (0.33 x 115 = 38.3). This is considerably less than the typical capacity of a free-flowing freeway lane (2000 vehicles/hour) so, at least initially, the system would not be the solution to traffic congestion that some may envision. However, future improvements in roadable aircraft automated control might allow the vehicle spacing to be tightened up and, if future improvements in speed are also achieved, the capacity of the system could increase substantially.

Route Difficulties

Following the interstate highway system becomes problematic in two instances: 1.) where the interstate highway crosses the airspace (Class B, C, or D) of an airport, and 2.) where the interstate highway system passes through a densely populated urban area. In both cases the problem could be solved by orienting the roadable aircraft route either around the airport airspace or around the circumference of an urban area. This would necessitate a deviation from the interstate alignment but, in most cases, the deviation would be relatively minor. Class B airspace with outer rings starting at 3500 feet AGL or above would be under flown by roadable aircraft and no deviation would be needed. If for some reason it is impossible or impractical to orient the route around the area in question then roadable aircraft may be forced to land and drive through the area, returning to the skies on the other side.

Coordination with Regular Aircraft

At the current time, roadable aircraft fall into the category of sport aircraft and a sport pilot license is required to fly one. In all likelihood, this would continue to be the case as the first roadable aircraft transportation system is developed. However, as technology advances, it is not hard to envision a time when roadable aircraft could be flown by individuals with no special training. If GPS-based vehicle control systems progress to the point where limited human interaction with the roadable aircraft is required while airborne, then any “average Joe” that has the financial resources to procure and operate the vehicle could make use of the system. When this occurs, our skies could quickly become filled with aircraft flying at low altitudes. To maintain order (and safety) within the system, and to provide suitable system capacity, roadable aircraft flown by your “average Joe” would be restricted to designated routes such as those discussed in this paper. However, those with a sport pilot license would be free to leave the system, enter Class E airspace, and take advantage of more direct routing and a greater choice of altitudes offered by the general aviation system.

To preserve order within the roadable aircraft system and to encourage proper aircraft spacing, transitions between the roadable aircraft system and the general aviation system would be restricted to designated points. In addition, all general aviation aircraft would be required to cross roadable aircraft routes at designated altitudes such as: < 1500 feet AGL, 2300 (+/- 100) feet AGL, or > 3100 feet AGL and no crossing of a roadable aircraft route could be made within 5 miles of a roadable aircraft runway at an altitude of less than 3100 feet AGL. This would prevent conflicts between “regular” aircraft and roadable aircraft that are taking-off or landing.

Weather

One of the primary advantages of roadable aircraft in comparison to “regular” general aviation aircraft is the ability of the roadable aircraft to safely deal with adverse weather conditions. Consider this internet essay by George Gregory [3]:

Anyone who has tried to travel VFR soon discovers how impractical it is. "Time to spare, go by air". Too many variables limit the effectiveness of a light aircraft for practical travel. Weather is probably the biggest problem; if the weather goes down, you either wind up cooling your heels in some motel somewhere, or you develop an intimate relationship with the side of a mountain.

We all know of people who paid the ultimate price for pushing the weather. And if you arrive, fair weather or foul, someone has to come and get you, or you have to rent a car. Not very convenient. And IFR? That's an expensive airplane to maintain, and an expensive rating to get and stay current in. VFR is costly enough! With a roadable aircraft, if the weather's coming down you can land enroute and drive through the stuff. VFR flight becomes a practical way to get about.

With relatively frequent runway locations enroute, the roadable aircraft system proposed in this paper makes air-to-road transition quick and easy. The key to safe operation will be the automated closure of air routes when weather conditions become unfavorable. Automated systems for collecting wind direction and speed data at each runway will allow automated closure of the runway should conditions become unsafe.

National Security

Having low level aircraft flying near areas that are sensitive from a national security standpoint would obviously be undesirable. It would be prudent to avoid such areas when establishing roadable aircraft routes, either by "bending" the routes away from these areas or, if that is not practical, forcing vehicles to land and drive past the sensitive area. Ensuring that roadable aircraft are not flown by individuals intent on doing harm to others would be another security challenge. Not only would roadable aircraft operators need to be properly licensed, some set of precautions would be required to keep unlicensed operators out of the driver's seat. Fingerprint recognition software or iris scanning technology might be the ultimate solution to this challenge.

Environmental Concerns

Keeping most roadable aircraft flight confined over non-urban interstate highways should minimize the noise impacts of relatively low level flight. However, these aircraft will definitely have a carbon footprint and will definitely consume energy; there is no doubt about that. But the argument can be made that the same holds true for automobiles or general aviation aircraft in general. The same future technological developments that will help make our land vehicles and our aircraft greener can be expected to benefit roadable aircraft as well. The fact that a vehicle can travel on both the ground and in the air does not necessarily make it any more onerous environmentally than a vehicle that does just one or the other.

Example System Design

Figure 4 contains a proposed roadable aircraft transportation system design for a portion of northern Florida and southern Georgia near Jacksonville, Florida. The air routes basically follow I-10, I95 and I-75 with three pure interstate air routes added to decrease travel time for roadable aircraft: GA8 across southern Georgia, FA2 across northern Florida, and GA1 connecting eastern Georgia and Florida. Since there are considerable air space issues around Jacksonville, and since it is a densely populated area, roadable aircraft must either bypass the urban area using the pure interstate air routes or must land and drive through the urban area. Near Valdosta, Georgia the air route is diverted away from the interstate to avoid the class D airspace associated with the Valdosta airport (KVAL). All air routes are designed to avoid class B, C and D airspace. Where practical, air routes even avoid airspace surrounding small non-towered airports where class E airspace extends lower than 1200 feet. However, since this type of airspace is so prevalent, and since it is generally associated with relatively minor airports, most air routes situated above the interstate system are not diverted to avoid this lowered class E airspace (as is the case near the interchange of I-75 and I-10). Consequently, general aviation operations at these minor airports will need to be conducted with the roadable aircraft system in mind.

All prohibited and restricted airspace must be avoided and the proposed system design does so. However, Military Operations Areas (MOA) are quite prevalent and they cannot be readily avoided without seriously limiting the geographical scope of the system. Fortunately, roadable aircraft will be operating under 3000 AGL and it will probably be possible to coordinate with the military to modify MOA operations in the vicinity of roadable aircraft routes in order to accommodate this new system.

Wilderness areas are another issue. It is desirable that aircraft maintain an altitude of 2000 feet AGL or greater over designated wilderness areas. In this example, pure interstate air route GA8 passes over the Okefenokee Swamp. Wilderness areas could be handled in one of two ways: 1.) the 2000 foot clearance could be reduced to 1600 feet within the limits of any interstate air route passing over a wilderness area, or 2.) the altitudes flown by roadable aircraft could be increased by 400 feet over wilderness areas.

The Proposed Short-Term System

The first roadable aircraft transportation system requires that all drivers have at least a sport pilot license with all aspects of flight, including runway selection, take-offs, landings, altitude selection, selection of cruise speed, and spacing selection being carried-out by the pilot in command. Flights are only allowed during daylight hours (from 1 hour before sunrise to 1 hour after sunset) under VFR weather conditions. Approaching bad weather, insufficient visibility, or contrary winds result in portions of the system being temporarily shut-down with roadable aircraft forced to land at the next available airstrip where wind and weather conditions are suitable.

Every roadable aircraft is equipped with a modern GPS system that displays the lateral limits of all air routes. The highway itself provides a visual ground reference with roadable aircraft being required to stay to the right of the highway centerline when operating on an overflight segment of the air route.

Roadable aircraft are issued a special ground transponder by the FAA. This transponder communicates with access gates at all interstate airstrips. The transponder is needed to gain access into or out of the airstrip and is used to automatically charge each roadable aircraft every time they use the airstrip via automatic debiting of funds from a pre-established account. This operation is similar to the way transponders are currently used on many US toll roads.

As time goes by and experience is gained with the system, roadable aircraft flights are allowed at night and under marginal VFR conditions.

The Proposed Long-Term System

The GPS system becomes integrated with the control system of the aircraft, allowing for complete automation of vehicle movement while in the air. Any licensed driver (with a special endorsement) is allowed to operate a roadable aircraft. The driver programs his or her desired departure airstrip and arrival airstrip into the advanced control system and the system does the rest, with the vehicle essentially flying itself. Altitude and spacing are automatically accommodated with all merges coordinated by the system. Fully automated control allows spacing to be reduced and system capacity correspondingly increased, while at the same time freeing the operator to complete other tasks while traveling. Operations are permitted at night and under IFR conditions, but not during severe weather or under other conditions that would make travel unsafe. To facilitate trip planning, advanced weather prediction algorithms provide drivers nationwide information on which interstate airstrips are expected to be open and which are expected to be closed during the next 24 hours.

In Conclusion

This paper describes what I believe is a workable system for roadable aircraft transportation, a system that is compatible with our existing air and ground transportation networks. Will the system be an attractive one in relation to car travel or commercial jet travel? That depends on many factors. However, as the calculations contained in Appendix A suggest, such a system would be cost competitive using today's prices for important items such as the value of travel time, the cost of fuel, and the capital cost of the roadable aircraft itself. For ultimate system success (high capacity, high safety, and competitive performance) automated vehicle control is the key, with human intervention removed to the maximum extent possible.

Roadable aircraft can be flown right now by any licensed pilot, including sports pilots. With approximately 500,000 licensed pilots in the United States [4], that's quite a potential market. As the vehicles become more automated over time, it may become prudent to develop a special class of roadable aircraft pilots who require even less training than a sport pilot and who are limited to flying within the roadable aircraft system. In fact, if roadable aircraft become extremely popular, we will be forced to limit these aircraft to some sort of space-restricted system like the one described in this paper to avoid the potentially unsafe scenario of vehicles flying every which way in uncontrolled airspace. Midair collisions are already a significant safety problem for general aviation aircraft and increasing the number of vehicles flying about without having a highly organized transportation system overseen by the latest GPS-based location and control technology would be patently irresponsible.

So how do we get started? The first roadable aircraft that will be readily available to the general public (the Transition) is not scheduled for delivery until the year 2011, so we have some time to plan. I would recommend selecting one state as a test ground for the concept. A state should be selected with optimum characteristics, such as good weather, a limited number of commercial airports, little restricted airspace to avoid, and lots of potential for the use of “pure” interstate air routes (routes with no interstate highway below) to improve the relative travel time of roadable aircraft and maximize their usefulness. A state like New Mexico or Nevada might fill the bill.

APPENDIX A - Travel Time and Cost Competitiveness of Roadable Aircraft

Some quick calculations show that roadable aircraft could be a competitive form of travel, especially when weather is an issue. For example, consider a two-person non-business trip of 350 miles between the southern suburbs of Jacksonville, Florida and downtown Miami, Florida via car, commercial jet, and roadable aircraft. Because this is an intercity non-business trip, we will value each person's time at $17.25 per hour. This value is consistent with the range of values advocated by the USDOT [5], when using the average wage rate of the last quarter of 2008 as the base value in accordance with information provided by the US Department of Labor [6].

Table 1 provides the cost calculations assuming good weather.

By car: With one 30 minute stop for a snack and/or refueling en route and an average interstate travel speed of 70 mph. The time to cover the 350 mile distance is **5.5 hours**. If the car gets 30 mpg, then, using a cost of $2.50 per gallon for regular unleaded gas, the out of pocket expense is about **$29** for the trip. The total costs for the trip includes non-out-of-pocket costs such as vehicle depreciation, maintenance and insurance. A typical value of $0.35/mile for all non-gas costs, which is the 2009 AAA medium sedan rate for a car travelling 20,000 miles per year [7], produces a total trip cost, ignoring travel time, of about $152. 5.5 hours of travel time at $17.25 per hour for two travelers is $190, producing a total trip cost of **$341**.

By commercial jet: The taxi drive time to the airport in Jacksonville is about 45 minutes and the taxi drive time from the Miami airport to downtown Miami is about 15 minutes. It would be reasonable to arrive at the Jacksonville airport 1 hour and 15 minutes prior to departure to ensure that we clear security and make the flight. Actual gate-to-gate flight time is about 1 hour and 15 minutes with an additional 15 minutes added to travel from the gate in Miami to the taxi stand (it is assumed that we have not checked any bags). The total trip time is **3.7 hours**. The two taxi rides total about $122 and the air fare would be about $150 per person for a total out of pocket cost of **$422**. The total trip cost, ignoring travel time, is also $422 since the out of pocket expenses are the only expenses incurred. 3.7 hours of travel time at $17.25 per hour for two travelers is about $127, producing a total trip cost of **$549**.

By roadable aircraft: Let's assume that we are working with the existing air transportation system for roadable aircraft (which is the existing system for general aviation aircraft) instead of the new system I am proposing in this paper. The first step would be to drive the vehicle to the St. Augustine airport which would take about 35 minutes. It would then take about 45 minutes to check the weather, develop a general flight plan, convert the vehicle for take-off, and take-off. The vehicle would be flown about 290 miles to Opa-Locka Executive airport located 10 miles north of downtown Miami which, at a cruise speed of 110 mph, which would take about 2.5 hours. Another 30 minutes would be required to land and convert the vehicle back to a car and then another 15 minutes would be required to drive the vehicle to downtown Miami. The total trip time is **4.6 hours**. The total distance driven as a car is 42 miles and using 30 mpg and $2.75 per gallon for premium gas produces a fuel cost of about $4 for the land portion of the trip. The air portion of the trip requires 12.6 gallons of fuel (2.52 hours x 5 gallons per hour) which costs about $35 for a total out of pocket cost of **$38** for the trip. A total of 14 gallons of fuel is used and, since this is less than 17.5 gallons (20 gallon capacity – required 2.5 gallon 30-minute reserve), no stop for refueling is needed. Assuming the following: insurance at $2000/year, annual maintenance and inspection at $4000/year, and annual depreciation at $14,000/year ($194,000 over 20 years at 5% with $50,000 salvage value), with 20,000 miles covered per year, produces a mileage-based non-fuel cost of $1.00 per mile. An additional $20.00 per hour in the air is required to cover oil, engine overhaul, and prop overhaul. The resulting total cost, ignoring travel time, is $317. 4.6 hours of travel time at $17.25 per hour for two travelers is $159, producing a total trip cost of **$476**.

By roadable aircraft, with new transportation system: Let's now assume that we are working with the new air transportation system for roadable aircraft that I am proposing in this paper. The first step would be to drive the vehicle 10 miles to runway A95S-2 located just south of the I-95/I-295 interchange in south Jacksonville, which would take about 15 minutes. It would then take about 15 minutes to convert the vehicle and take-off. The vehicle would be flown about 305 miles to runway ATPS-7 located just north of the Florida Turnpike Extension/Dolphin Expressway interchange, situated about 10 miles west of downtown Miami. At a cruise speed of 110 mph, this would take about 2.7 hours. Another 15 minutes would be required to land and convert the vehicle back to a car and then another 15 minutes would be required to drive the vehicle to downtown Miami. The total trip time is about **3.6 hours**. The total distance driven as a car is 20 miles and using 30 mpg and $2.75 per gallon for premium gas produces a fuel cost of about $2 for the land portion of the trip. The air portion of the trip requires 15.8 gallons of fuel (3.15 hours x 5 gallons per hour) which costs about $43 for a total out of pocket cost of **$45** for the trip. A total of 16.5 gallons of fuel is used and, since this is less than 17.5 gallons (20 gallon capacity – required 2.5 gallon 30-minute reserve), no stop for refueling is needed. Assuming the following: insurance at $2000/year, annual maintenance and inspection at $4000/year, and annual depreciation at $14,000/year ($194,000 over 20 years at 5% with $50,000 salvage value), with 20,000 miles covered per year, produces a mileage-based non-fuel cost of $1.00 per mile. An additional $20.00 per hour in the air is required to cover oil, engine overhaul, and prop overhaul. The resulting total cost, ignoring travel time, is $332. 3.6 hours of travel time at $17.25 per hour for two travelers is $123, producing a total trip cost of **$455**.

So, with good weather, the roadable aircraft is 33% more expense than driving a car for this trip but 17% less expensive than flying by commercial jet. An additional advantage for the car and roadable aircraft alternatives includes having the vehicles available for in-town trips at the destination.

If we re-do the calculations assuming a 2 hour delay due to adverse weather, the roadable aircraft costs the same as driving a car for the trip (**$341**), since we would choose to drive the roadable aircraft instead of waiting, and it is 45% less expensive than flying by commercial jet (**$618**). It is interesting to note that it is actually less costly to drive the roadable aircraft on this particular trip than to fly it (but not nearly as much fun).

The cost of driving a car or a roadable aircraft remains the same regardless of whether the adverse weather conditions last for a short time or a long time. The costs of commercial jet travel rise by $34.50 for each hour of delay. However, the non-monetary aggravation of totally missing an engagement in another town or being stuck overnight in a distant city is a substantial negative factor.

In this example, the highway route between the trip origin (Jacksonville) and the trip destination (Miami) is very direct with I-95 running between the two cities. The cost advantage of a roadable aircraft in relation to driving starts to appear when the highway route between the origin and destination is indirect, as might be the case in a mountainous area or an area covered with bodies of water. A trip between Charleston, West Virginia and Washington, D.C. or between Grand Rapids, Michigan and Milwaukee, Wisconsin would be two good examples.

REFERENCES

1. Wikpedia, Flying Car (Aircraft), http://en.wikipedia.org/wiki/Flying_car_(aircraft)

2. Terrafugia Roadable Aircraft, www.terrafugia.com

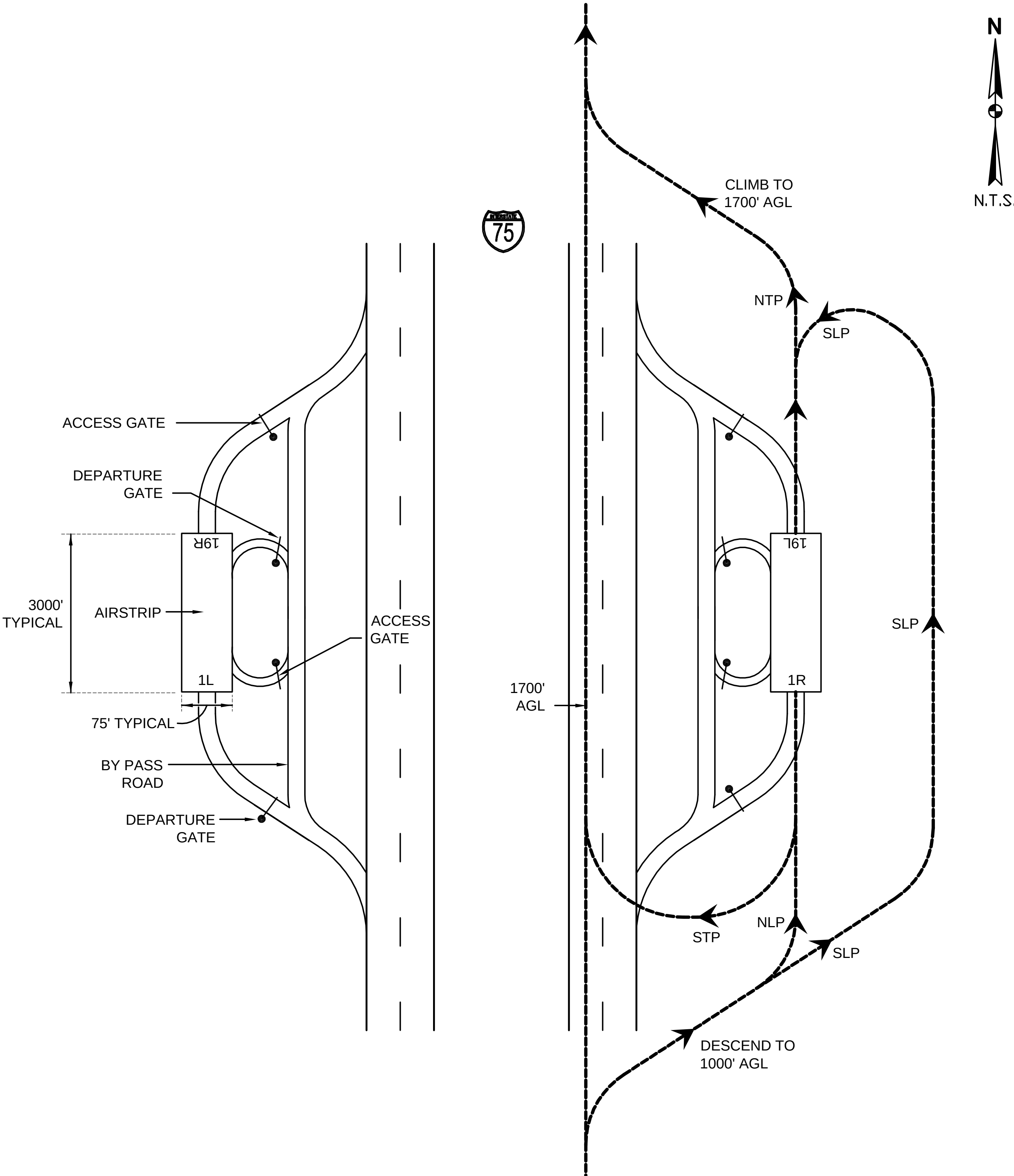
3. George Gregory Essay, http://www.roadabletimes.com/roadables-integ_gregessay.html

4. U.S. Federal Aviation Administration, http://registry.faa.gov/activeairmen

5. U.S. Department of Transportation (USDOT), "The Value of Saving Travel Time, Departmental Guidance for Conducting Economic Evaluations", Office of the Secretary of Transportation, February 2003

6. Bureau of Labor Statistics, United States Department of Labor, http://www.bls.gov/news.release/cewqtr.t04.htm

7. American Automobile Association, "Your Driving Costs, Behind the Numbers", 2009 Edition



A75N INTERSTATE PATHS

NLP = NORTHBOUND LANDING PATH
SLP = SOUTHBOUND LANDING PATH
NTP = NORTHBOUND TAKE-OFF PATH
STP = SOUTHBOUND TAKE-OFF PATH

FIGURE 1

PROPOSED
TYPICAL INTERSTATE
RUNWAY LAYOUT

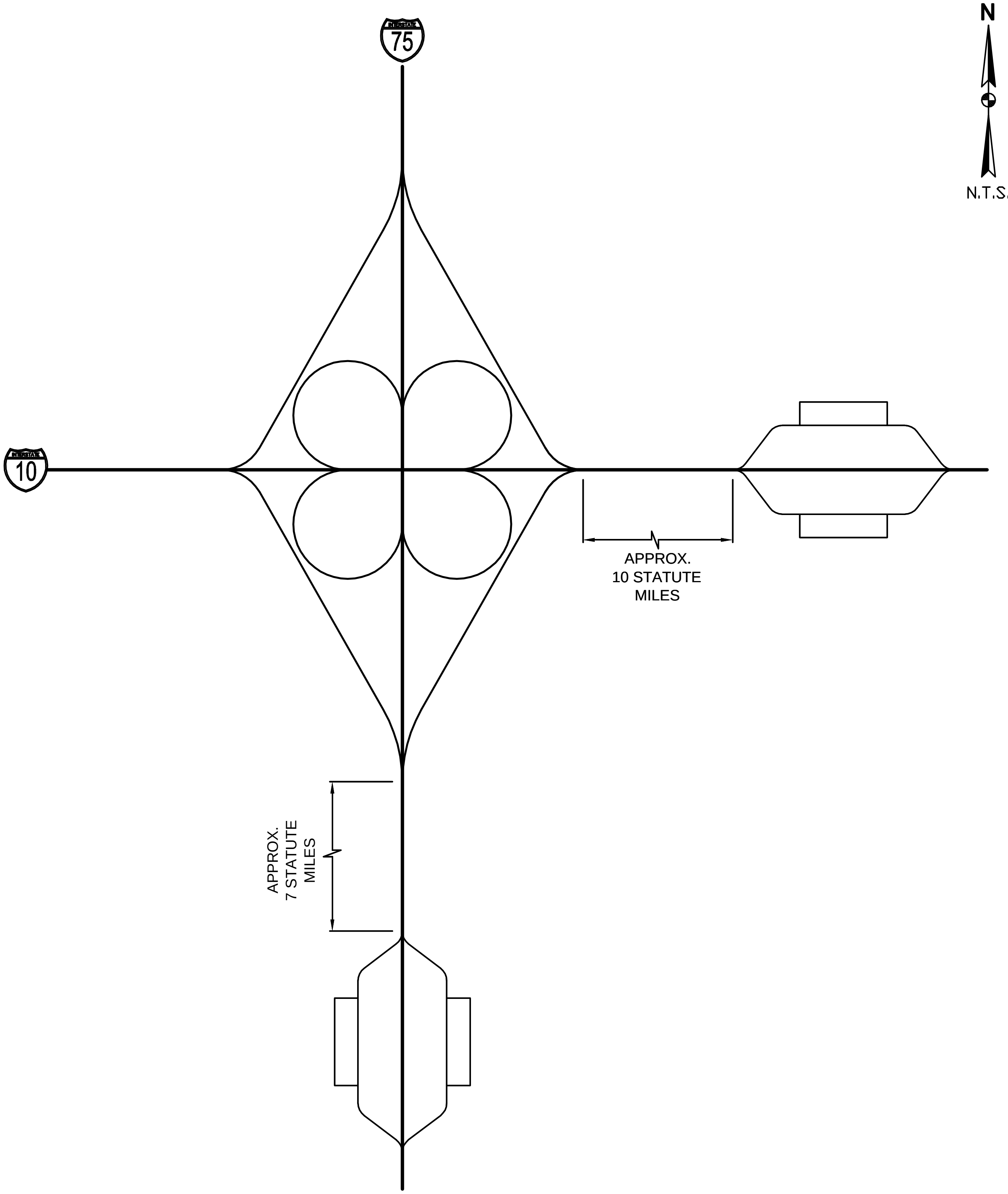


FIGURE 2

PROPOSED RUNWAYS
AT FREEWAY-TO-FREEWAY
INTERCHANGE

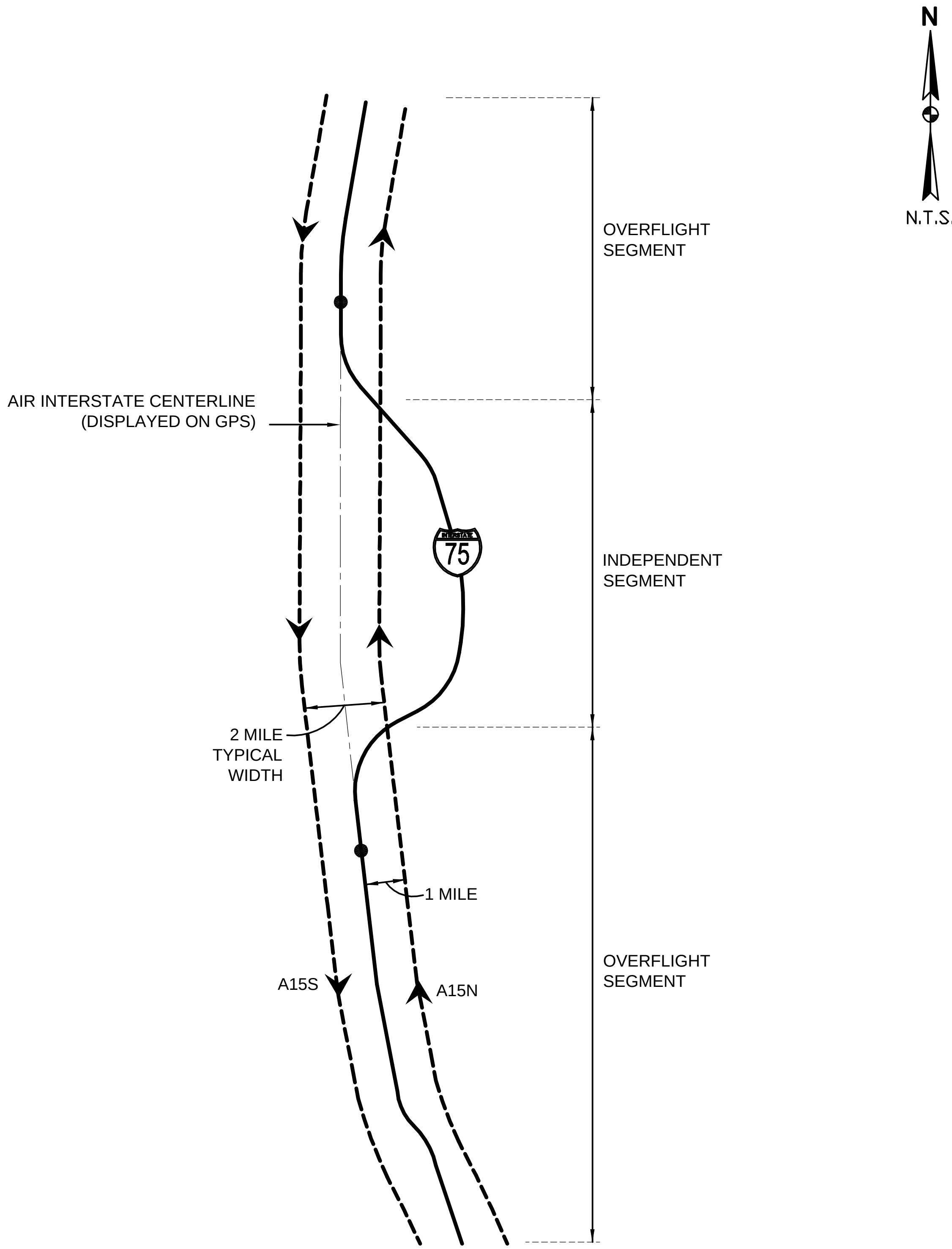


FIGURE 3

TYPICAL INTERSTATE
AIR CORRIDOR
FOR ROADABLE AIRCRAFT

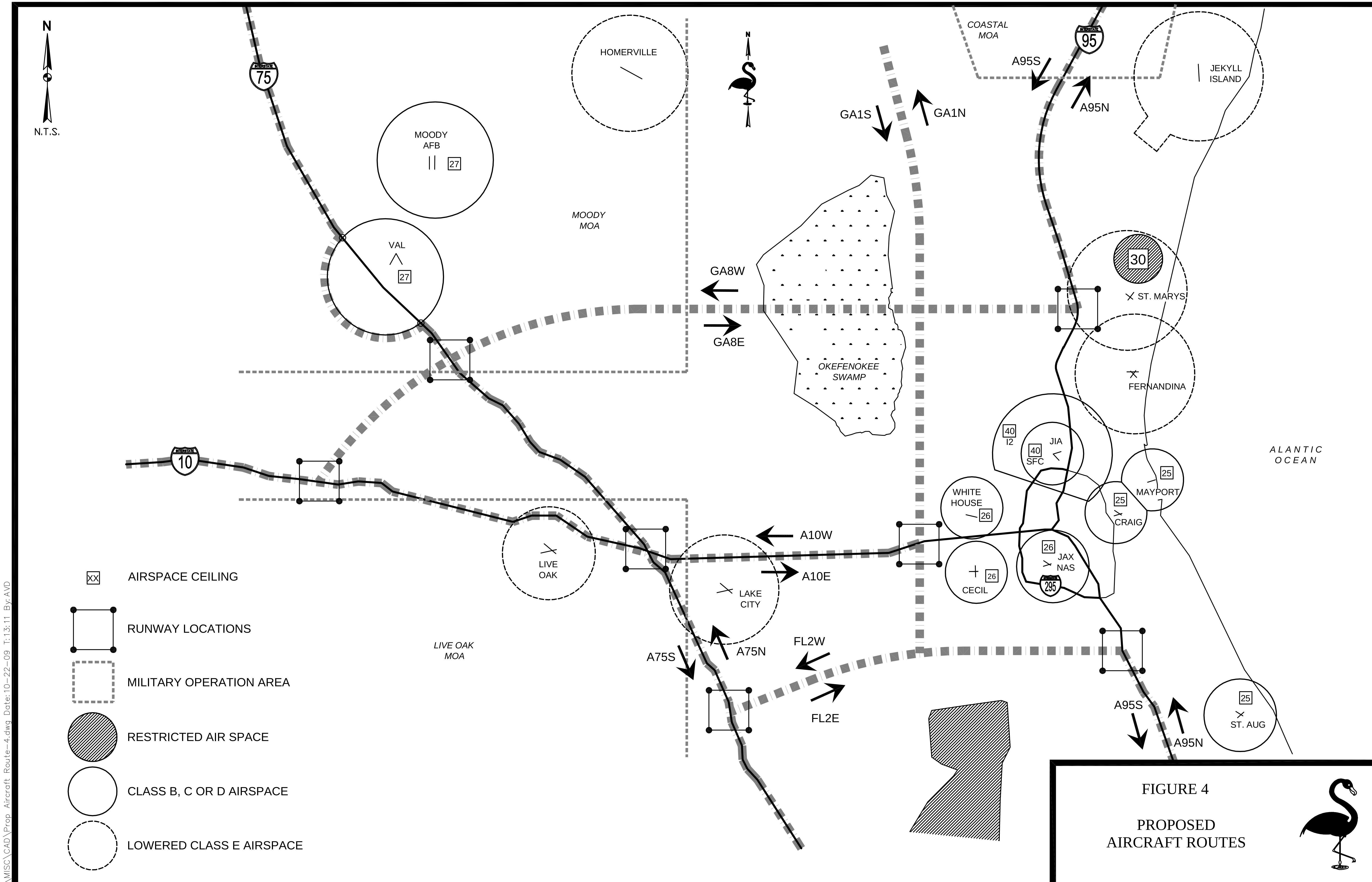


FIGURE 4

PROPOSED
AIRCRAFT ROUTES

Y:\MISC\CAD\Prop Aircraft Route-4.dwg Date:10-22-09 T:13:11 By:AVD

TABLE 1
Travel Cost Comparison by Mode

Jacksonville (south) **to** **Miami (downtown)** **Good Weather**

CAR		
Item	Value	Units
Road Distance	350	statute miles
Speed	70	statute miles/hour
Drive Time	5.00	hours
Rest Time	0.50	hours
Road Travel Time	**5.50**	hours
Total Travel Time	**5.50**	hours
Value of Time	$ 17.25	$ /hour/person
Number of Travellers	2	people
Time Cost	$ 189.75	$
Road Fuel Usage	30	statute miles/gallon
Fuel Price	$ 2.50	$ /gallon
Road Fuel Cost	$ 29.17	$
Road Operation Price	$ 0.35	$ /mile *
Road Operation Cost	$ 122.50	$
Out of Pocket Cost	**$ 29.17**	$
Total Cost	**$ 341.42**	$
Percent cost increase over car:		

COMMERCIAL JET		
Item	Value	Units
Road Distance (Taxi)	50	statute miles
Speed	50	statute miles/hour
Drive Time	1.00	hours
Road Travel Time	**1.00**	hours
Air Distance	335	statute miles
Cruise Speed	500	statute miles/hour
Origin Airport Time	1.25	hours
Take-Off Time	0.25	hours
Fly Time	0.67	hours
Landing Time	0.25	hours
Destination Airport Time	0.25	hours
Air Travel Time	**2.67**	hours
Total Travel Time	**3.67**	hours
Value of Time	$ 17.25	$ /hour/person
Number of Travellers	2	people
Time Cost	$ 126.62	$
Taxi Price	$ 2.25	$ /mile
Taxi Cost	$ 122.50	$
Ticket Price	$ 150.00	$ /person
Ticket Cost	$ 300.00	$
Out of Pocket Cost	**$ 422.50**	$
Total Cost	**$ 549.12**	$
	161%	

ROADABLE AIRCRAFT - Existing System		
Item	Value	Units
Road Distance	42	statute miles
Speed	50	statute miles/hour
Drive Time	0.84	hours
Road Travel Time	**0.84**	hours
Air Distance	290	statute miles
Cruise Speed	115	statute miles/hour
Origin Airport Time	0.50	hours
Take-Off Time	0.25	hours
Fly Time	2.52	hours
Landing Time	0.25	hours
Destination Airport Time	0.25	hours
Air Travel Time	**3.77**	hours
Total Travel Time	**4.61**	hours
Value of Time	$ 17.25	$ /hour/person
Number of Travellers	2	people
Time Cost	$ 159.11	$
Road Fuel Usage	30	statute miles/gallon
Fuel Price	$ 2.75	$ /gallon
Road Fuel Cost	$ 3.85	$
Air Fuel Usage	5	gallons/hour
Air Fuel Cost	$ 41.55	$
Road Operation Price	$ 0.25	$ /mile
Road Operation Cost	$ 10.50	$
Milage Air Operation Price	$ 0.75	$ /mile
Hourly Air Operation Price	$ 20.00	$ /hour
Air Operation Cost	$ 267.93	$
Out of Pocket Cost	**$ 45.40**	$
Total Cost	**$ 482.94**	$
	141%	

ROADABLE AIRCRAFT - New System			
	Item	Value	Units
	Road Distance	20	statute miles
	Speed	50	statute miles/hour
	Drive Time	0.40	hours
	Road Travel Time	**0.40**	hours
	Air Distance	305	statute miles
	Cruise Speed	115	statute miles/hour
	Origin Runway Time	0.00	hours
	Take-Off Time	0.25	hours
	Fly Time	2.65	hours
	Landing Time	0.25	hours
	Destination Runway Time	0.00	hours
	Air Travel Time	**3.15**	hours
	Total Travel Time	**3.55**	hours
	Value of Time	$ 17.25	$ /hour/person
	Number of Travellers	2	people
	Time Cost	$ 122.55	$
	Road Fuel Usage	30	statute miles/gallon
	Fuel Price	$ 2.75	$ /gallon
	Road Fuel Cost	$ 1.83	$
	Air Fuel Usage	5	gallons/hour
	Air Fuel Cost	$ 43.34	$
	Road Operation Price	$ 0.25	$ /mile
	Road Operation Cost	$ 5.00	$
**	Milage Air Operation Price	$ 0.75	$ /mile
***	Hourly Air Operation Price	$ 20.00	$ /hour
	Air Operation Cost	$ 281.79	$
	Out of Pocket Cost	**$ 45.18**	$
	Total Cost	**$ 454.52**	$
		133%	

***** insurance, repair-maintenance, and depreciation cost
45.5 cents/mile total - 10.5 cents/mile gas = 35 cents/mile
SOURCE: 2009 AAA for medium size sedan going 20,000 miles/year

****** insurance, inspection, repair-maintenance, and depreciation cost
$2000/yr insurance, $1000/yr inspection, $3000/yr repair, $14,000/yr depreciation
20,000 miles per year, 75% in the air (130 hours in the air)
depreciation: $194,000 price, $50,000 salvage value over 20 years at 5% interes

******* oil ($2/hr), engine overhaul ($15/hr), and prop overhaul ($3/hr)

Origin Runway: I-95 South of I-295 in South Jacksonville
Destination Runway: Turnpike Ext North of Dolphin Xway