



Zip Aviation

Initial Total Operating Cost Comparison

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Electric Propulsion Energy Cost



At least a 4x reduction in energy cost

1 gal 100LL fuel = 35.3 kW hr

Current average 100LL cost is \$6.20 per gallon, yielding a cost of \$.155 /kWhr

Current average cost per kW/hr of electricity = \$.115 /kWhr (\$.06 off peak)

Aviation gas cost to electricity ratio = 1.52x

Electric motor/controller/battery conditioner system efficiency = 90%

Aircraft engine that achieves a .45 brake specific fuel consumption = 28%

Electric motor to piston engine efficiency ratio = 3.21x

Overall decrease in energy cost due to propulsion system change = 4.89x

If batteries charged at off-peak/commercial electricity rates, the decrease in energy cost = 9.37x

A decrease in energy cost by even more than an order of magnitude is not only possible, but likely....

Electric Propulsion Energy Cost



Energy cost comparison does not take into account that electric aircraft can be more aerodynamically efficient (at 150 or 200 mph).

Prior concept comparison (SR-20 vs eSwift-2) yielded a 11x difference in energy cost. If off peak electric rates were also applied the result would have been 21x reduction.

Prior concept comparison (SR-22 vs eATLIT) yielded a 12.6x difference in energy cost. If off peak electric rates were also applied the result would have been 24x reduction.

Comparing against the Eclipse 500 yields even greater differences.

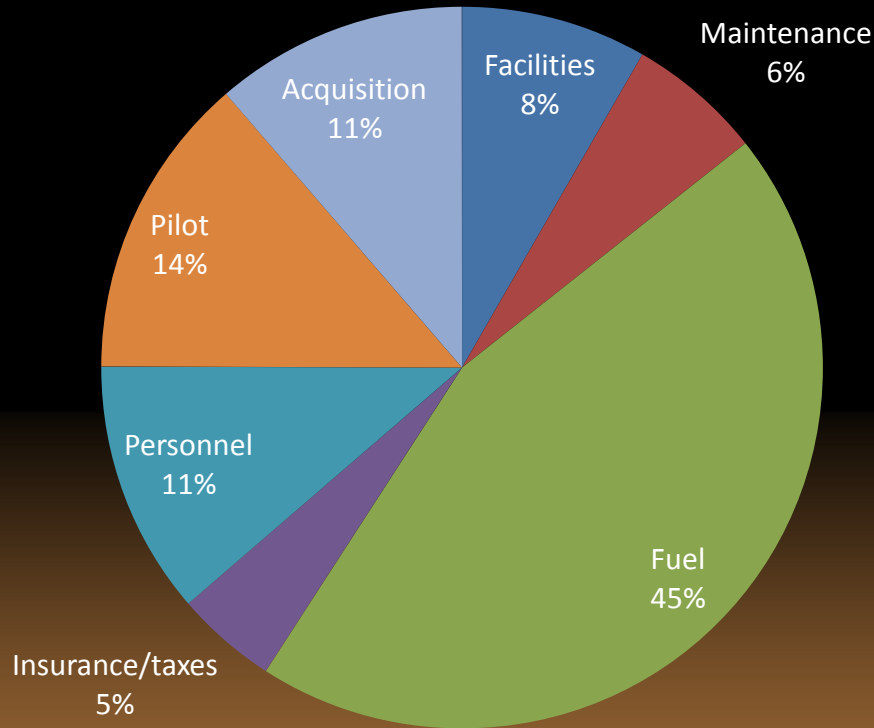
	Spectrum 33	Eclipse 500	Citation Mustang	Citation CJ1+	Citation CJ2 +	Hawker 400A	King Air B200
300 nm							
Flight time (hr+mn)	0 + 53	0 + 54	0 + 58	0 + 52	0 + 51	0 + 48	1 + 07
Fuel Used (lbs)	617	622	709	848	960	1,098	711
Altitude	FL350	FL180	FL350	FL350	FL350	FL370	FL210
Specific Range (nm/lb)	0.49	0.48	0.42	0.35	0.31	0.27	0.42
Est. Fuel cost / Mile	\$1.23	\$1.24	\$1.41	\$1.69	\$1.91	\$2.19	\$1.41

Cirrus SR-20 Fuel Cost ~ \$.34/mile (3.6x less than Eclipse 500)

Total Operating Cost



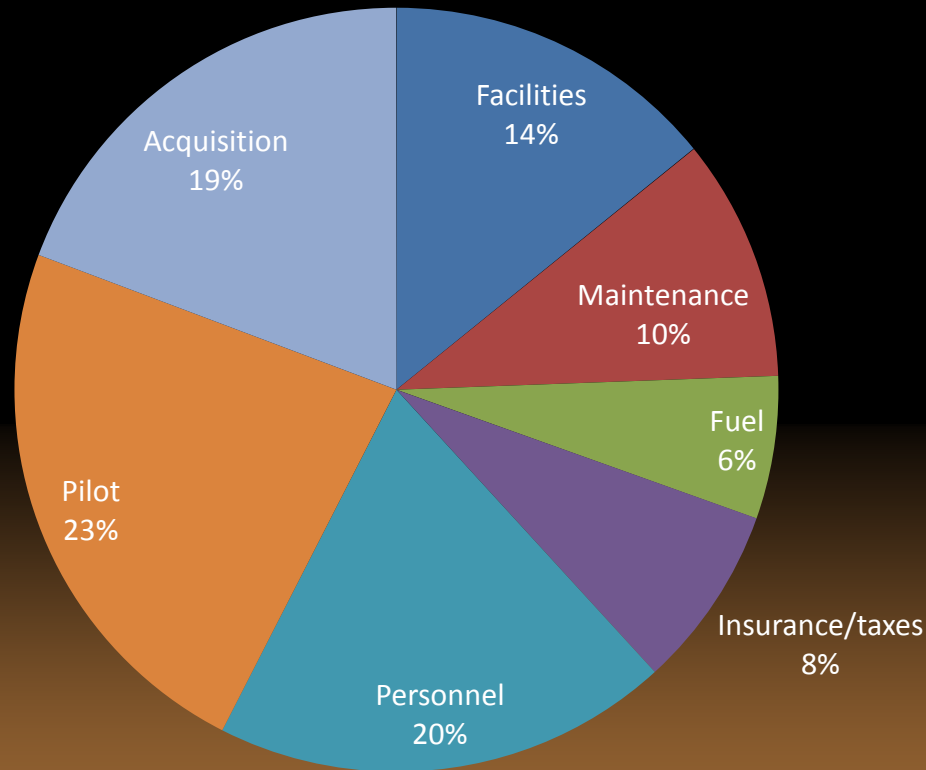
SR-22T (\$440/hr)
Base



Total Operating Cost



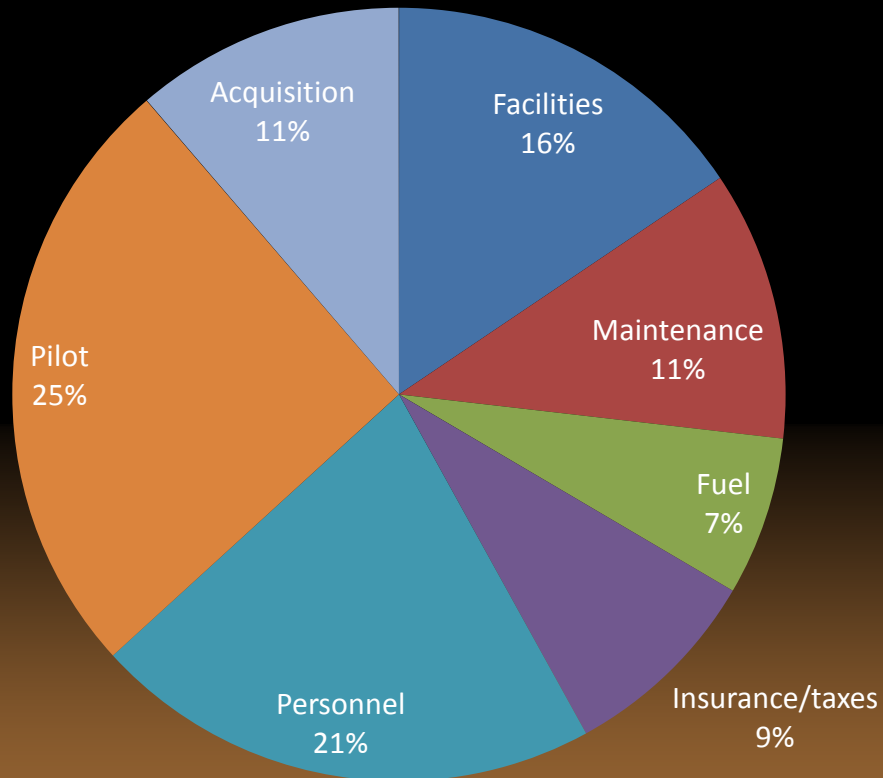
**With eATLIT Fuel Cost (\$259/hr)
58% of Base**



Total Operating Cost



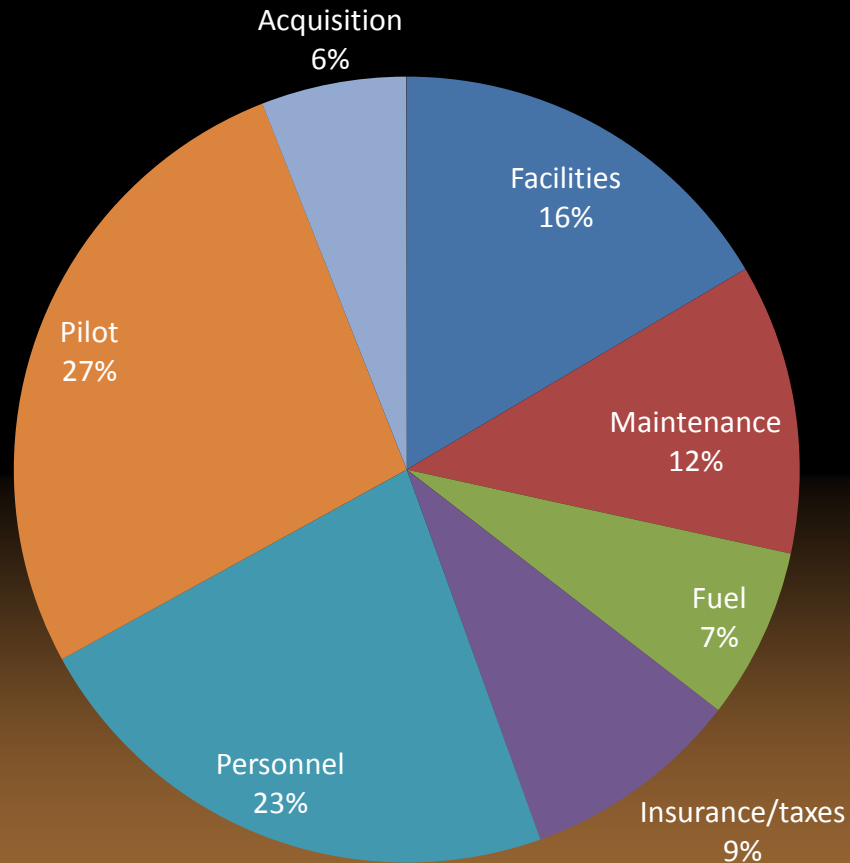
Utilization from 800 to 1500 hrs/year (\$235/hr)
53% of Base



Total Operating Cost



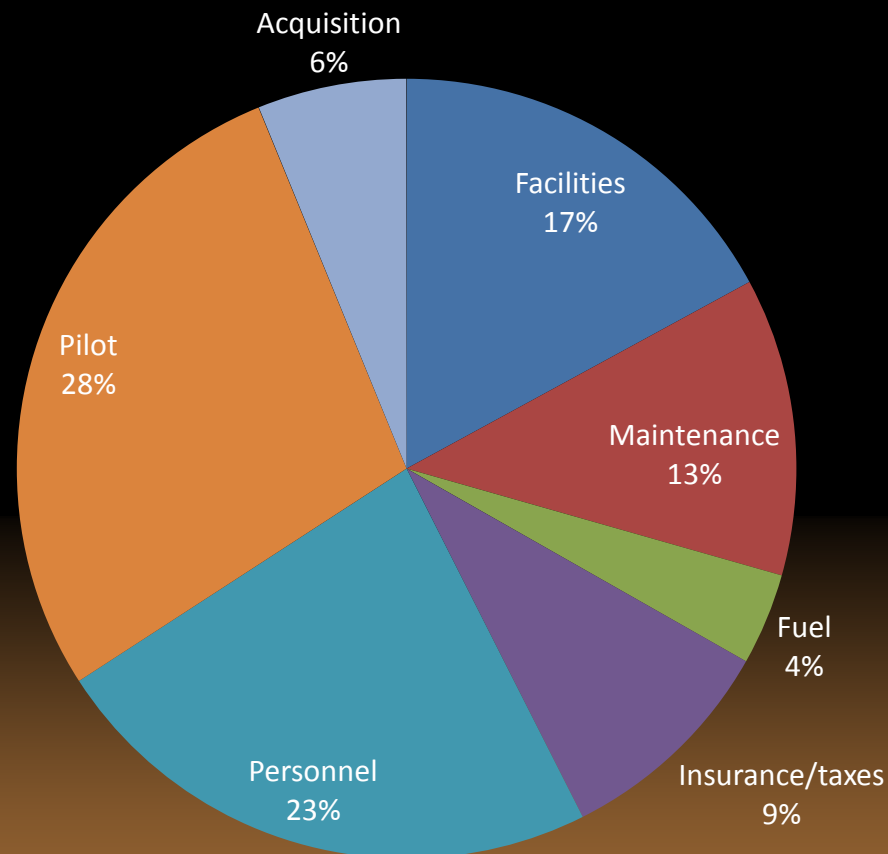
**Annual Utilization from 1500 to 3000 hrs (\$222/hr)
50% of Base**



Total Operating Cost



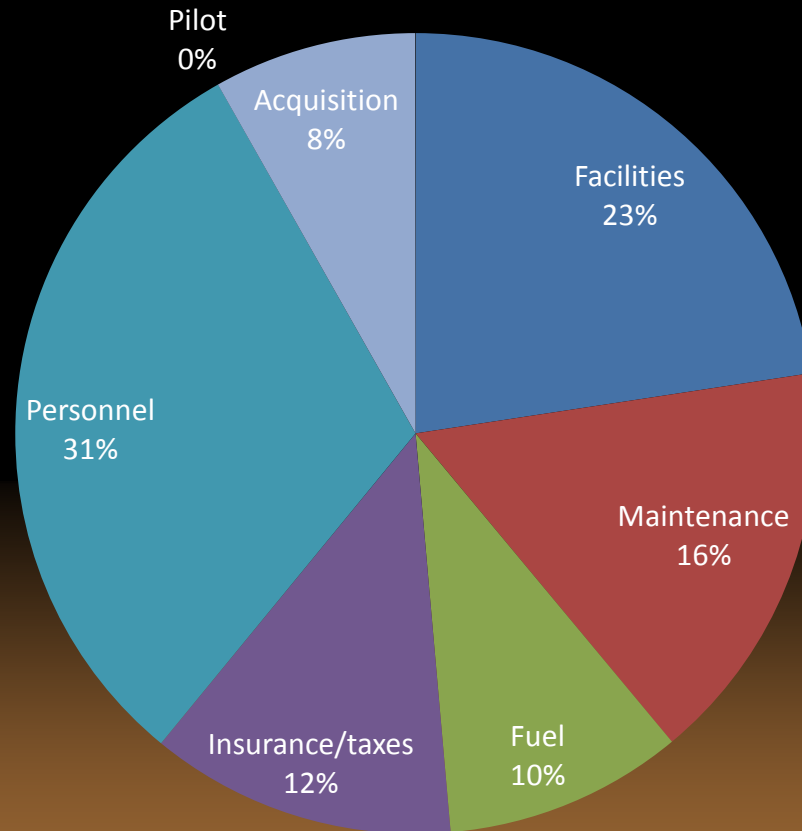
Off Peak Battery Recharge (\$215/hr)
48% of Base



Total Operating Cost



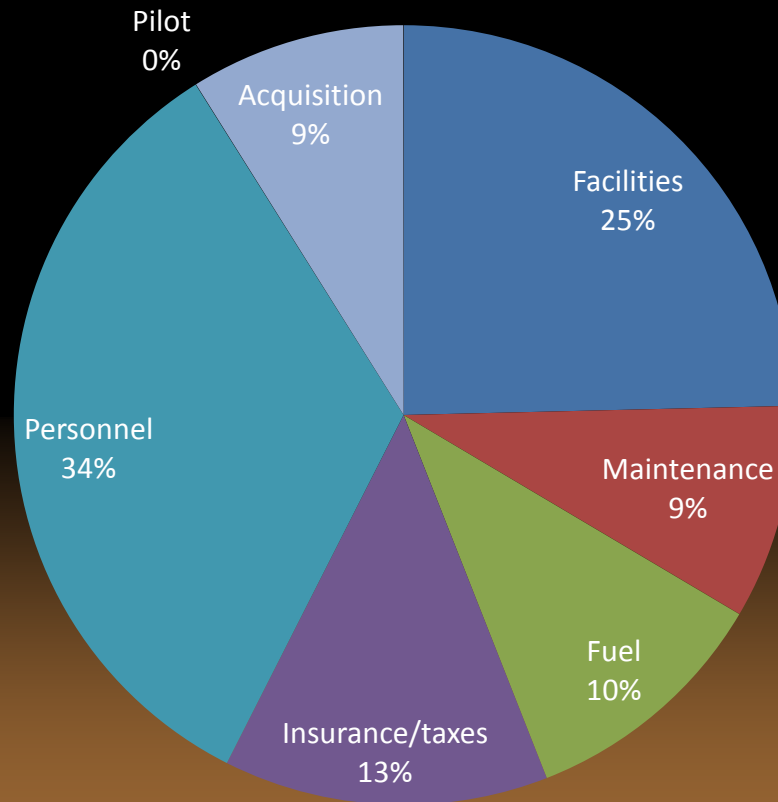
**Free Autonomy (\$162/hr)
37% of Base**



Total Operating Cost



**Maintenance Reduction of 50% (\$148/hr)
33% of Base**





Propulsion System Cost

Argonne Lab motor cost goals

2012	\$17/kW
2015	\$12/kW
2025	\$ 5/kW

Controller costs

\$20/kW
\$15/kW
\$ 5/kW

Argonne Lab Battery Costs

2012	\$500 /kWhr
2015	\$300 /kWhr
2025	\$150 /kWhr

Comparative Propulsion System Cost (for 200 mile range)

Cirrus SR-22 motor (310 hp, Teledyne Continental IO-550-N)	\$60,000
2012 Electric (176 hp + 66 kW battery)	\$39,512
2015 Electric (176 hp + 66 kW battery)	\$24,552
2025 Electric (176 hp + 66 kW battery)	\$11,660

Autonomy Cost



Hardware costs are generally estimated using price data for commercial, non-certified avionics targeted towards the experimental/ homebuilt market. When flight-critical availability and fail-operation performance is required, triple redundant hardware is assumed. Since the cost estimates are based on current low-volume avionics market, it is reasonable to assume the economies of scale could reduce costs if higher-volumes are achieved. This is not reflected in the current estimates. LIDAR sensor cost assumes significant cost reduction over current prices (~\$70K) based on use in high-volume automotive applications.

Software costs are assumed to be dominated by the non-recurring development cost and no recurring costs are included. For practical purposes, software cost per unit results from the allocation of development costs across an estimated fleet size.

Development costs consist of an educated estimate of the additional cost, beyond the current state of the art, needed to develop and demonstrate the required level of functionality. Costs are in millions of dollars. These estimates result from a combination of the complexity of a function and its criticality. Certification costs for functionality radically beyond the proven, state-of-practice (i.e. fully-autonomous outer-loop) are highly uncertain and have the potential to exceed the estimated cost by a factor of 2 or more.

Autonomy Cost



	Highly Automated	Semi-Autonomous	Fully-autonomous
Autonomy, Outer loop			
Optical sensors	0	500	1000
infrared sensor	0	2500	2500
LIDAR	0	0	5000
Computer	0	1200	3600
Flight controls / autopilot			
Servos (\$800/servo)	2400	7200	7200
Sensors (ADAHRS)	1200	3600	3600
Flight computer	1200	3600	3600
Operator Interface			
Primary flight display	3400	3400	0
Multi-funciton display	3400	3400	3400
Trip planner/e-flight bag	1000	1000	1000
Haptic interface	0	3000	0
Supporting Avionics			
Navigation	2000	4000	4000
Voice comm	3000	3000	3000
Data comm	0	3000	3000
Traffic surviellence	975	975	1950
Health-monitoring	500	2400	2400
Total Recurring Hardware	\$ 19,075.00	\$ 42,775.00	\$ 45,250.00
Development Costs			
Autonomy, Outer loop	0	100	1000
Flight controls / autopilot	0	100	100
Operator Interface	10	40	10
Supporting Avionics	0	0	0
Total Development (\$ millions)	\$ 10.00	\$ 240.00	\$ 1,110.00