Specific Range Solutions Ltd.
"Your partner in flight optimization"
omer.majeed@srs.aero / 1.613.883.5045
www.srs.aero

TBM 850 Fuel Consumption and Block Time Analysis for a Typical Short-Haul Flight

Executive Summary

This paper evaluates the impact of cruise power setting on total fuel consumption and block time based on a simulated short-haul flight between Ottawa and Toronto of a Socata TBM 850, a light single-engine turboprop aircraft. The effects of altitude, upper winds and air temperature are also assessed.

The most efficient flight profile for the trip based on actual forecast winds and temperatures in terms of minimum fuel consumption is Long-Range Cruise at 30,000 ft with a total fuel burn of 382.5 lb and a block time of 87.4 min. The minimum time profile based on the same forecast is Normal/Maximum Cruise at 24,000 ft with a block time of 75.9 min and a total fuel burn of 416.2 lb.

The following general conclusions were reached:

- Fuel consumption is minimized using Long-Range Cruise and increases progressively through the Normal and Maximum Cruise throttle settings, respectively;
- Increasing cruise altitude decreases fuel consumption, as does increasing air temperature;
- Headwinds increase both fuel consumption and block time, for tailwinds the converse is true;
- Block time can be minimized by either increasing the throttle setting and/or by selecting a flight profile that will generate the highest average ground speed.

It would be useful to develop a rule-based flight planning tool that would enable optimization of fuel burn or block time based on aircraft configuration, altitude, wind and temperature inputs. The application could even be used in flight to adjust for changing conditions.

Figure 1 – Socata TBM 850 at Le Bourget (2007)

1.0 Introduction

This study evaluates the impact of cruise power setting on total fuel consumption and block time for a simulated short-haul flight of a light single-engine turboprop aircraft. The effects of altitude, upper winds and air temperature are also assessed. The aircraft chosen for the study was the Socata TBM 850, which is powered by a Pratt & Whitney Canada PT6A-66D engine. The mission defined for analysis is a relatively short IFR flight carrying four passengers from Ottawa MacDonald-Cartier International Airport (CYOW) to Toronto Buttonville Airport (CYKZ) per Figure 2, a distance of 182 nautical miles. The aircraft performance calculations were based on the TBM 850 Pilot's Operating Handbook (POH) per Ref. 4.1.

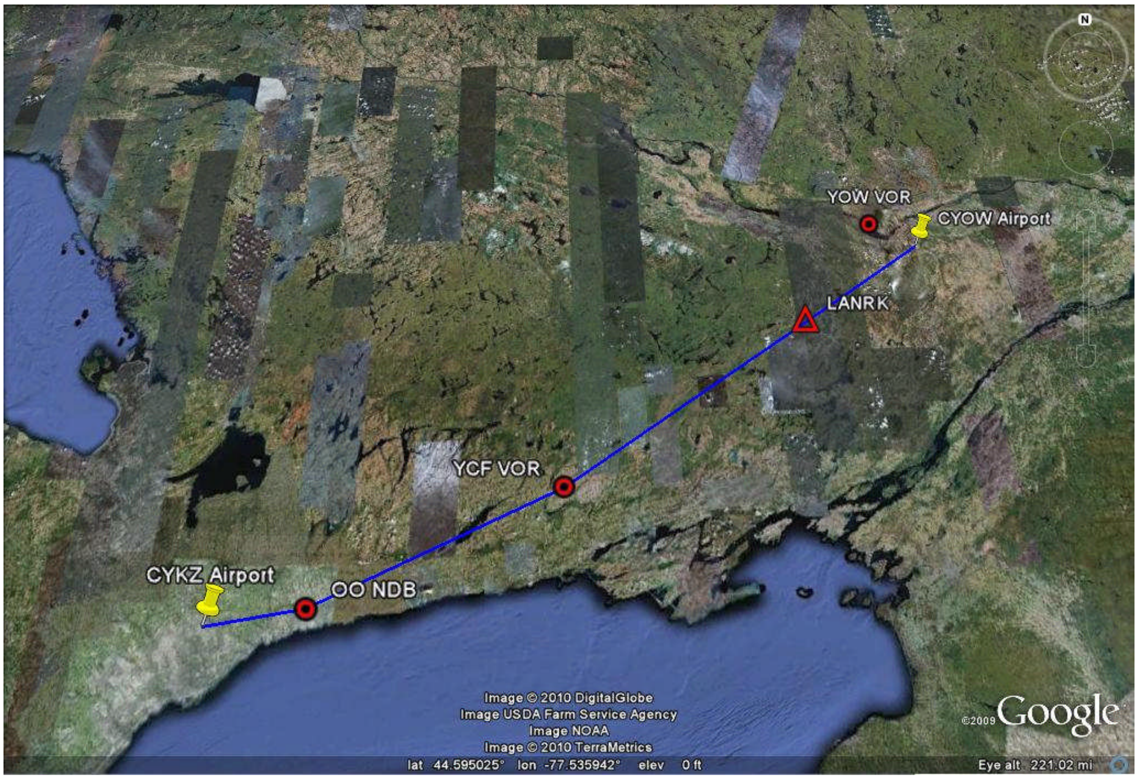

Figure 2 – Ottawa International (CYOW) to Toronto Buttonville (CYKZ) Routing

2.0 Discussion

The forecast weather for flight planning purposes was obtained from NAV Canada's website for a 15:00 UTC (10:00 am local) departure on January 22nd, 2009.

The baseline flight profile involves a maximum power climb at 130 KIAS to 30,000 ft or FL300, followed by a cruise segment at that altitude and a Continuous Descent Approach (CDA) at 150 KIAS and a descent rate of 2,000 fpm to the destination. The maximum flight altitude of the TBM 850 of 31,000 ft was not used due to Air Traffic Control separation rules. Fuel consumption varies from 382.5 lb for the Long-Range Cruise power setting to 402.2 lb for the Maximum Cruise power setting, the block times varies from 87.4 min. to 78.9 min per Table 1. The fuel consumption and block times are plotted in Figures 3 and 4, respectively. Note that for start up and taxi out, 15 minutes at idle power was assumed and for taxi in and shut down, 10 minutes at idle power was assumed[1]. By pulling the throttle back to the Long-Range Cruise setting, 19.7 lb or 4.9% of fuel is saved, but the flight will have an 8.5 min. or 10.8% longer block time compared to the Maximum Cruise setting. The reason for the small difference in the fuel burn is due to the relatively short length of the cruise phase of 115.9 NM. Specific Range is a fuel efficiency parameter based on distance covered per unit of fuel burned, typically expressed in NM/lb. Specific Range for the entire mission is 0.476 NM/lb at Long-Range Cruise, 0.456 NM/lb at Normal Cruise and 0.453 NM/lb at Maximum Cruise per the forecast weather and cruising at FL300.

[1] Fuel consumption for taxi, take-off and descent flight phases were estimated due to the data not being available in the POH.

Compared to calculations at ISA conditions at FL300, the fuel consumption and block times using the forecast upper wind and temperature data are significantly higher for all cruise throttle settings. This is due primarily to the relatively strong winds from the northwest at altitude varying from 300^o at 97 knots at the start of the trip (CYOW) to 310^o at 63 knots by the end of the trip (CYYZ), although the marginally colder temperatures (ISA-5^{o}C) at altitude also contribute to slightly higher fuel burn. The colder, denser air generates more drag and also more power, however there is relatively higher fuel consumption. In Normal Cruise at FL300 with an aircraft weight of 6,300 lb, the instantaneous Specific Range[2] is 0.836 NM/lb at ISA-5^{o}C, but improves by 2.0% to 0.853 NM/lb at ISA conditions per the POH.

A check on the calculations was performed using published data. Per Ref. 4.2, the Time and Fuel vs. Distance Chart indicates that 392 lb of fuel would be consumed over 225 NM at the Long-Range Cruise setting with NBAA IFR reserves (100 NM), zero wind, ISA and a 658 lb payload. Using linear interpolation, this results in 317.1 lb of fuel burned over 182 NM. This compares to 334.2 lb of fuel consumption calculated over 182 NM at the Long-Range Cruise setting at FL300 at ISA with 45 min IFR reserves and 4 passengers aboard using the SRS' methodology. The calculations in this paper are within 5% of the published performance data and therefore, in reasonable agreement.

Flight planning analysis was also performed for a cruise altitude of 24,000 ft or FL240 using forecast wind and temperature data to evaluate the effect of the lower altitude on fuel burn and block time. While the air is denser at lower altitude, which increases fuel consumption, the predicted winds were slightly more favourable compared to FL300: 300^o at 86 knots above CYOW and 300^o at 62 knots above CYYZ. The reason why cruising at lower altitude is less efficient is because more drag is generated for a given True Air Speed due to higher air density. More power is also generated, but this drives up fuel consumption and the net impact is a lower Specific Range compared to higher altitudes. The fuel burn varies from 399.4 lb for the Long-Range Cruise power setting to 416.2 lb for the Normal and Maximum Cruise power settings[3], the block times vary from 93.7 min. to 75.9 min. Expressed in percentages, the Long-Range setting burns 4.0% less fuel, but takes 23.5% more time compared to the Normal and Maximum settings. Specific Range for the entire mission at FL240 with the forecast weather is 0.456 NM/lb at Long-Range Cruise and 0.437 NM/lb at Normal and Maximum Cruise. In Normal Cruise under ISA conditions with an aircraft weight of 6,300 lb, the instantaneous Specific Range is 0.714 NM/lb at FL240, but improves by 19.5% to 0.853 NM/lb at FL300 per the POH.

The True Air Speed is significantly reduced at FL240 with the Long-Range throttle setting, therefore explaining the significantly greater block time. However, the FL240 cruise altitude profile is faster than the FL300 profile: 75.9 min versus 79.5 min for Normal Cruise power and 75.9 min versus 78.9 min for Maximum Cruise power. This is primarily due to the time saved by avoiding the additional climb to FL300 at 130 KIAS and by avoiding additional descent from FL300 at 150 KIAS.

Analysis Case	Flight Analysis Description	Long-Range Cruise Total Fuel Burn (lb)	Normal Cruise Total Fuel Burn (lb)	Maximum Cruise Total Fuel Burn (lb)
1	Cruise @ FL300 - Forecast Wx	382.5	398.9	402.2
2	Cruise @ FL300 - ISA	334.2	347.9	349.4
3	Cruise @ FL240 - Forecast Wx	399.4	416.2	416.2

Analysis Case	Flight Analysis Description	Long-Range Cruise Block Time (min)	Normal Cruise Block Time (min)	Maximum Cruise Block Time (min)
1	Cruise @ FL300 - Forecast Wx	87.4	79.5	78.9
2	Cruise @ FL300 - ISA	76.8	72.4	71.8
3	Cruise @ FL240 - Forecast Wx	93.7	75.9	75.9

Analysis Case	Flight Analysis Description	Long-Range Cruise Specific Range (NM / lb)	Normal Cruise Specific Range (NM / lb)	Maximum Cruise Specific Range (NM / lb)
1	Cruise @ FL300 - Forecast Wx	0.476	0.456	0.453
2	Cruise @ FL300 - ISA	0.545	0.523	0.521
3	Cruise @ FL240 - Forecast Wx	0.456	0.437	0.437

Table 1 - TBM 850 Fuel Consumption, Block Times & Specific Range for Short-Haul Flight
CYOW to CYKZ (182 NM), 4 Pax, IFR Reserves

[2] Instantaneous Specific Range = KTAS (NM/hr) / Fuel Consumption (lb/hr)
[3] The Normal and Maximum Cruise power settings are identical at FL240 and ISA-5^{o}C.

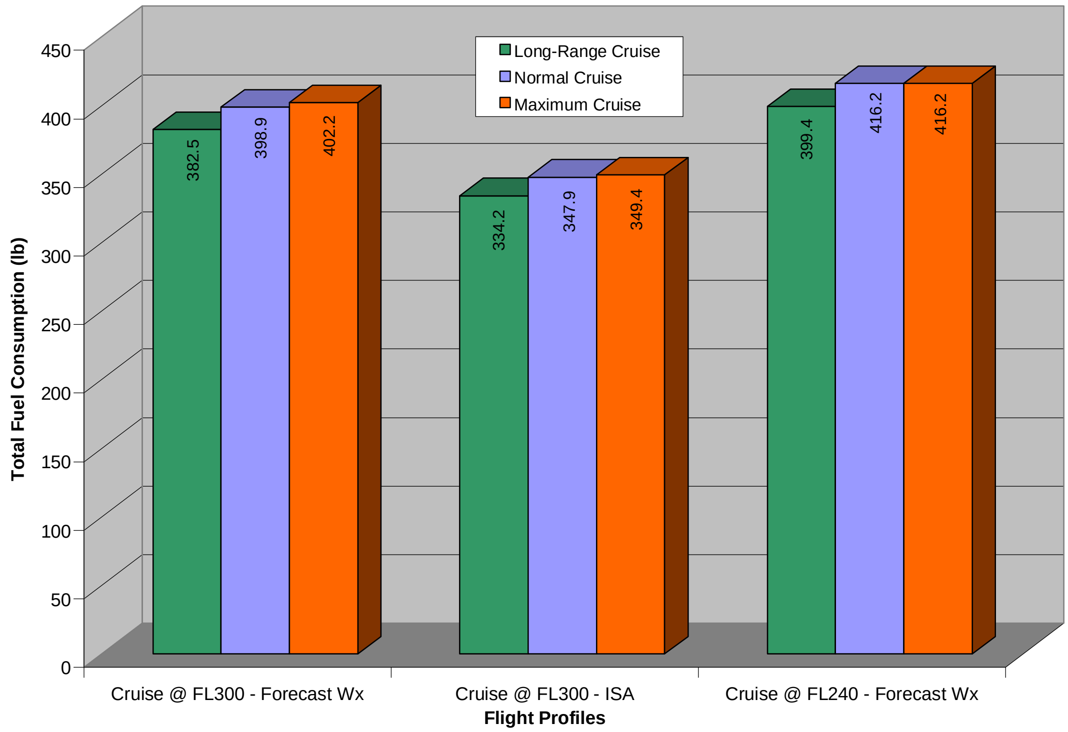

Figure 3 - TBM 850 Fuel Consumption for Short-Haul Flight
CYOW to CYKZ (182 NM), 4 Pax, IFR Reserves

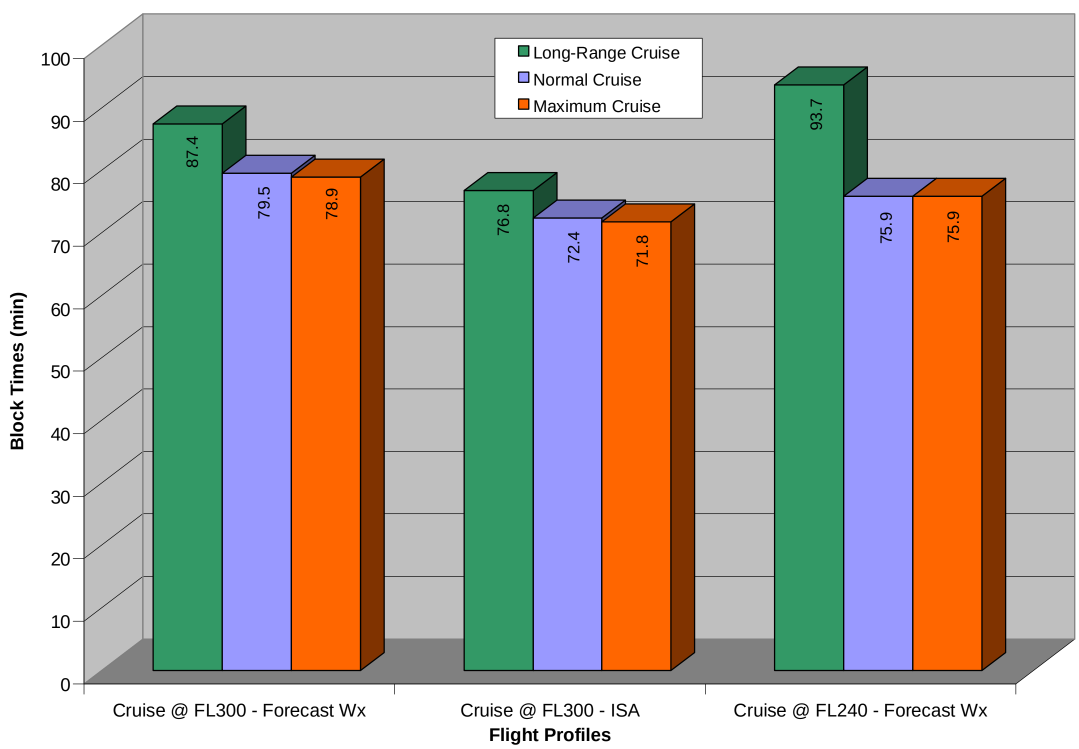

Figure 4 - TBM 850 Block Times for Short-Haul Flight
CYOW to CYKZ (182 NM), 4 Pax, IFR Reserves

3.0 Conclusions

The most efficient flight profile for the Ottawa to Toronto trip based on the forecast winds and temperatures in terms of minimum fuel consumption is Long-Range Cruise at FL300 with a total fuel burn of 382.5 lb and a block time of 87.4 min. The fastest profile is Normal/Maximum Cruise at FL240 with a block time of 75.9 min and a total fuel burn of 416.2 lb.

The following general conclusions were reached:

- Fuel consumption is minimized using Long-Range Cruise and increases progressively through the Normal and Maximum Cruise throttle settings, respectively;
- Increasing cruise altitude decreases fuel consumption, as does increasing air temperature;
- Headwinds increase both fuel consumption and block time, for tailwinds the converse is true;
- Block time can be minimized by either increasing the throttle setting and/or by selecting a flight profile that will generate the highest average ground speed.

Flight planning needs to evaluate a range of cruise altitudes and throttle settings to determine the optimum profile based on either minimum fuel burn, minimum time or a balance between the two. The longer the leg, the more worthwhile it is to climb to the highest possible altitude for maximum fuel efficiency, however winds and temperatures always need to be taken into account.

It would be useful to develop a rule-based flight planning tool that would enable optimization of fuel burn or block time based on aircraft configuration, altitude, wind and temperature inputs. The application could even be used in flight to adjust for changing conditions.

4.0 References

4.1 TBM 850 Pilot's Operating Handbook, *Section 5 Performance, Rev. 0*

4.2 Business & Commercial Aviation, April 2007 Issue – *EADS Socata TBM 850 Flight Report pg. 62–69.*