Appendices
Final Report
Aviation Fuel Efficiency Technology Assessment (AFETA) Study

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APPENDIX A—Market Forecast Analysis Model

The overall market forecast was estimated based on analyzing available data sources (Embraer, Boeing, FAA, and Ascend) to develop the market forecast and capture assumptions used in the study. The most detailed data source available was the 2013 Embraer and Boeing market forecasts. The basis for the overall market forecast was Embraer's 2013 Market Outlook due to its compatibility with seat count classifications of the reference aircraft.

To develop the overall delivery quantity to base the model forecast model, specific quantities per aircraft type (e.g., A318, A319, A320, A321, etc.) were grouped to generate historical 2011/2013 delivery quantities. Prior production quantities (through 2011) were extracted from publically available data. Calculation of Market Share is based on the 2011/2012 production quantities of the reference aircraft vs the 2011/2012 production quantities of all aircraft within the class. Table A-1 shows the summary of the 2011 and 2012 deliveries obtained from the Embraer forecast by aircraft class.

TABLE A-1 – 2011/2012 AIRCRAFT DELIVERIES

Class	Size Breakout	# Projected Aircraft (2012-2031)	Competing Aircraft	Prior Quantity (thru 2011)	2011 Deliveries	2012 Deliveries	Market Share (based on 2011-2012 Deliveries)
Single Aisle	120 to 210 Seats	17,305	A319	1357	47	38	
			A320*	3192	306	332	38%
			A321	775	66	83	
			B737-800		372	415	
			A320neo Family				
			B737 MAX Family				
			CS300				
Small Twin Aisle	210+	6,795	A330		87	101	
			A340		0	2	
			A380		26	30	
			B787		3	46	
			B777*	983	73	83	32%
			B747		9	31	
Regional Jet	61-90 Seats	2,626	E170		2	1	
			E175		9	22	
			CRJ701		2	0	
			CRJ705		0	0	
			CRJ900		16	6	
			Antonov An-148		3	5	
			ARJ-21				
			Mitsubishi MRJ90				
	91-120 Seats	3,765	E190*	382	69	65	59%
			E195		24	23	
			A318		3	0	
			B-737-600		0	0	
			CRJ1000		17	8	
			Superjet 100		5	12	
			CS100				

This data set identified fleet size in 2011, projected deliveries in 2012, and estimated fleet size in 2031. From this data, fleet attrition rate was obtained from Embraer by vehicle class and the data was used to forecast the average annual fleet growth required to obtain the 2031 fleet size. An annual forecast model was then constructed from this data to estimate fleet size, annual attrition quantity, and estimated purchase quantity by year. This was done by building a model that estimated replacement of the fleet due to attrition and then assuming an initial purchase quantity in 2013 and applying a flat annual percent increase to achieve the overall fleet size. This results in a market forecast that grows over the years from 2013 through 2031. These resulting annual purchase buy quantities were used as the overall market forecast.

Table A-2 summarizes the 2011-2013 Embraer information the calculated and identified attrition, and the underlying growth and attrition rates used develop the overall market forecast based on the attrition methodology.

TABLE A-2 – ATTRITION METHOD (BASED ON EMBRAER MARKET OUTLOOK)

	SA	STA	RJ
2011 Fleet	10,215	3,180	1,435
2031 Fleet	18,900	7,085	4,020
2012-2031 New Aircraft	17,305	6,185	3,765
2034-2032 Attrition (Embraer)	8,620	2,280	1,180
2012-2032 Attrition (Calculated)	8,621	2,279	1,178
Calculated Fleet Growth Rate	3.124%	4.087%	5.286%
Assumed Fleet Attrition Rate	3.102%	2.385%	2.409%
Market share for modeled type	**38%**	**32%**	**59%**

The model assumptions of annual sales increase and attrition where then continued out to the year 2043 to allow for calculation of three time periods: 1) time period before 2024 EIS (2013-2023); 2) ten-year procurement period for the 2024 EIS (2024-2033); and ten-year procurement period for the 2034 EIS (2034-2043). Tables A-3.1 through A-3.4 show the overall forecasted demand and fleet size by aircraft class over the timeframe of the analysis. This table covers the timeframe from 2011 through 2043 and provides the overall market demand for the aircraft class. The highlighted items in the below tables are those that are used in the study to drive prior quantities and annual procurement demand for each aircraft class. This used with the assumed market capture is the basis for determining the single vendor forecasted buy quantity.

TABLE A-3.1 – MARKET TOTAL DEMAND (2011-2018)

		1	2	3	4	5	6	7
MARKET TOTAL DEMAND	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Single Aisle								
Fleet Size	10,215	10,534	10,863	11,202	11,552	11,913	12,285	12,669
Fleet Attrition		317	327	337	347	358	370	381
Total Demand (w/Attrition)		636	656	676	697	719	742	765
Total Buy Quantity		242	249	257	265	273	282	291
Cumulative Buy Quantity	3,192	3,434	3,683	3,940	4,205	4,478	4,760	5,051
Medium Small Twin Aisle								
Fleet Size	3180	3310	3445	3586	3733	3886	4045	4210
Fleet Attrition		76	79	82	86	89	93	96
Total Demand (w/Attrition)		206	214	223	233	242	252	261
Total Buy Quantity		66	68	71	75	77	81	84

MARKET TOTAL DEMAND	2011	1 2012	2 2013	3 2014	4 2015	5 2016	6 2017	7 2018
Cumulative Buy Quantity	983	1,049	1,117	1,188	1,263	1,340	1,421	1,505
Regional Jet								
Fleet Size	1,435	1511	1591	1675	1764	1857	1955	2058
Fleet Attrition		35	36	38	40	42	45	47
Total Demand (w/Attrition)		111	116	122	129	135	143	150
Total Buy Quantity		65	68	72	76	80	84	89
Cumulative Buy Quantity	382	447	515	587	663	743	827	916

TABLE A-3.2 – MARKET TOTAL DEMAND (2019-2027)

MARKET TOTAL DEMAND	8 2019	9 2020	10 2021	11 2022	12 2023	13 2024	14 2025	15 2026	16 2027
Single Aisle									
Fleet Size	13,065	13,473	13,894	14,328	14,776	15,238	15,714	16,205	16,711
Fleet Attrition	393	405	418	431	444	458	473	487	503
Total Demand (w/Attrition)	789	813	839	865	892	920	949	978	1,009
Total Buy Quantity	300	309	319	329	339	350	361	372	383
Cumulative Buy Quantity	5,351	5,660	5,979	6,308	6,647	6,997	7,358	7,730	8,113
Medium Small Twin Aisle									
Fleet Size	4382	4561	4747	4941	5143	5353	5572	5800	6037
Fleet Attrition	100	104	109	113	118	123	128	133	138
Total Demand (w/Attrition)	272	283	295	307	320	333	347	361	375
Total Buy Quantity	87	91	94	98	102	107	111	116	120
Cumulative Buy Quantity	1,592	1,683	1,777	1,875	1,977	2,084	2,195	2,311	2,431
Regional Jet									
Fleet Size	2167	2282	2403	2530	2664	2805	2953	3109	3273
Fleet Attrition	50	52	55	58	61	64	68	71	75
Total Demand (w/Attrition)	159	167	176	185	195	205	216	227	239
Total Buy Quantity	94	99	104	109	115	121	127	134	141
Cumulative Buy Quantity	1,010	1,109	1,213	1,322	1,437	1,558	1,685	1,819	1,960

TABLE A-3.3 – MARKET TOTAL DEMAND (2028-2035)

MARKET TOTAL DEMAND	17 2028	18 2029	19 2030	20 2031	21 2032	22 2033	23 2034	24 2035
Single Aisle								
Fleet Size	17,233	17,771	18,326	18,899	19,489	20,098	20,726	21,374
Fleet Attrition	518	535	551	568	586	604	623	643
Total Demand (w/Attrition)	1,040	1,073	1,106	1,141	1,176	1,213	1,251	1,291
Total Buy Quantity	395	408	420	434	447	461	475	491
Cumulative Buy Quantity	8,508	8,916	9,336	9,770	10,217	10,678	11,153	11,644
Medium Small Twin Aisle								
Fleet Size	6284	6541	6808	7086	7376	7677	7991	8318
Fleet Attrition	144	150	156	162	169	176	183	191
Total Demand (w/Attrition)	391	407	423	440	459	477	497	518
Total Buy Quantity	125	130	135	141	147	153	159	166
Cumulative Buy Quantity	2,556	2,686	2,821	2,962	3,109	3,262	3,421	3,587
Regional Jet								
Fleet Size	3446	3628	3820	4022	4235	4459	4695	4943
Fleet Attrition	79	83	87	92	97	102	107	113
Total Demand (w/Attrition)	252	265	279	294	310	326	343	361
Total Buy Quantity	149	156	165	173	183	192	202	213
Cumulative Buy Quantity	2,109	2,265	2,430	2,603	2,786	2,978	3,180	3,393

TABLE A-3.4 – MARKET TOTAL DEMAND (2036-2043)

MARKET TOTAL DEMAND	25 2036	26 2037	27 2038	28 2039	29 2040	30 2041	31 2042	32 2043
Single Aisle								
Fleet Size	22,042	22,731	23,441	24,173	24,928	25,707	26,510	27,338
Fleet Attrition	663	684	705	727	750	773	797	822
Total Demand (w/Attrition)	1,331	1,373	1,415	1,459	1,505	1,552	1,600	1,650
Total Buy Quantity	506	522	538	554	572	590	608	627
Cumulative Buy Quantity	12,150	12,672	13,210	13,764	14,336	14,926	15,534	16,161
Medium Small Twin Aisle								
Fleet Size	8658	9012	9380	9763	10162	10577	11009	11459
Fleet Attrition	198	206	215	224	233	242	252	263
Total Demand (w/Attrition)	538	560	583	607	632	657	684	713
Total Buy Quantity	172	179	187	194	202	210	219	228
Cumulative Buy Quantity	3,759	3,938	4,125	4,319	4,521	4,731	4,950	5,178
Regional Jet								
Fleet Size	5204	5479	5769	6074	6395	6733	7089	7464
Fleet Attrition	119	125	132	139	146	154	162	171
Total Demand (w/Attrition)	380	400	422	444	467	492	518	546
Total Buy Quantity	224	236	249	262	276	290	306	322
Cumulative Buy Quantity	3,617	3,853	4,102	4,364	4,640	4,930	5,236	5,558

A recent data from ASCEND showing 2014 deliveries was made available during the course of the study. This data was obtained and reviewed to identify if any changes in the market forecast needed to be implemented. Comparisons of the market forecast with ASCEND 2014 deliveries and out-years indicated that the overall market forecast assumptions in this study were reasonable. Table A-4 displays the 2014 ASCEND delivery data by Aircraft.

TABLE A-4 – ASCEND 2014 DELIVERY COUNT

Count of Aircraft Manufacturer Row Labels	Total
737 (NG)	470
700	11
800	386
900	70
BBJ	3
A319	34
100	33
ACJ	1
A3320	302
200	302
A321	150
200	150
Grand Total	**956**

APPENDIX B—Candidate Technology Evaluation Datasheet

The following subsections provide a breakdown of each major section of the questionnaire used by the SMEs for the technology evaluation.

Technology Summary Information

1. Title (common name)
2. Area of Impact: Propulsion, Aerodynamics, Structure, Operations
3. Brief Description
4. Baseline availability date for TRL 7
5. Baseline availability date in a production aircraft (TRL 9+)
6. Estimated performance % improvement for component
7. Estimated performance % improvement for aircraft
8. Source/references
9. ROM cost to develop and implement
10. Applicable Aircraft (SA/STA): Y/N

Technology Readiness Level (TRL) Progression

1. Current TRL: _______
2. Expected time (months) from Current TRL to TRL7: _______ ; +/- months for 75% confidence _______.
3. Expected time (months) from TRL7 to TRL9: _______ ; +/- months for 75% confidence _______.

Technology Maturation

1. What scope of work is needed to go from Current TRL to TRL6: ___________.
2. Est. Number and Types of Tests from Current TRL to TRL6: _________.
3. Est. level of effort* from Current TRL to TRL6: __________.
4. What scope of work is needed to go from TRL6 to TRL7: _________________.
5. Est. Number and Types of Tests from TRL6 to TRL7: ________.
6. Est. level of effort (labor hours) from TRL6 to TRL7 *(if possible, separate effort levels by skill areas, e.g., engineering vs. manufacturing):* ________.
7. What scope of work is needed to go from TRL7 to TRL9: _________________.
8. Est. level of effort from TRL7 to *TRL9 (if possible, separate effort levels by skill areas, e.g., engineering vs. manufacturing)*: ______.
9. Est. Number and Types of Tests from TRL7 to TRL9: ______.

Additional Characteristics

1. Is technology incorporating an additional element or replacing an existing item? ___________.
   a. If modifying, what items are we modifying? __________________.
   b. If modifying, what is the level of the change (mass, size, aerodynamics, etc.)? ________________.
   c. If modifying, what is the change in the relative complexity? ______________.
   d. If new, what is physical description? _________________________.
2. What subsystems are impacted? ___________________________________.
3. Are there reasonable analogies, which can be used for any subsystems?
4. What types of subsystems and/or services are required to implement the technology?
   a. Electrical: ___________; new or A/C supplied __________;
   b. Electronics: ___________; new or A/C supplied __________;
   c. Mechanical: ___________; new or A/C supplied __________;
   d. Hydraulic: ___________; new or A/C supplied __________;
   e. Pneumatic: ___________; new or A/C supplied __________;
   f. Other (name): __________; new or A/C supplied __________;

Piano 5 User Factors

Identify the impact on the User Factor as compared to the reference aircraft for the technology candidate.

user-cds-increment	user-factor-on-cruise-rating
user-factor-on-wing-drag	user-factor-on-continuous-rating
user-factor-on-fuse-drag	user-factor-on-takeoff-clmax
user-factor-on-nac-drag	user-factor-on-landing-clmax
user-factor-on-stab-drag	user-factor-on-takeoff-l/d
user-factor-on-fin-drag	user-factor-on-landing-l/d
user-factor-on-induced-drag	user-factor-on-total-drag
user-factor-on-divergence-mach	user-factor-on-taxi-out-fuel
user-factor-on-box-mass	user-factor-on-takeoff-fuel
user-factor-on-flap-mass	user-factor-on-approach-fuel
user-factor-on-fuse-mass	user-factor-on-taxi-in-fuel
user-factor-on-stab-mass	user-factor-on-asymmetric-drag
user-factor-on-fin-mass	user-factor-on-windmill-drag
user-factor-on-u/c-mass	user-factor-on-diversion-fuel
user-factor-on-sfc	user-factor-on-hold-fuel
user-factor-on-takeoff-rating	user-adjust-cl-cd-curve
user-factor-on-climb-rating	user-adjust-mach-cd-curve

APPENDIX C—Candidate Technology Evaluation

The following details a summary of the list of candidate technologies assessed in the study. The data shows by Technology Candidate a summary of the entry TRL level as of the time of the study, the forecasted complete TRL by 2017 and the overall forecasted improvement for each Technology Deployment Scenario.

TABLE C-1A – SA CANDIDATE TECHNOLOGY LIST

Single Aisle					2024			2034		
Technology Group	Technology	Code	Starting TRL	Est. TRL yr 2017 (Evol. Scenario)	Evol.	Mod.	Aggr.	Evol.	Mod.	Aggr.
Aerodynamic Efficiency (Viscous) % Improvement values are in drag component, 100% deployment	Natural laminar flow on nacelles	AV-1	TRL 9	TRL 9	1%	1.25%	1.50%	1.25%	1.50%	1.50%
	Hybrid laminar flow on empennage	AV-2	TRL 4	TRL 6		2%	2%	2%	2%	2%
	Natural laminar flow on wings	AV-3	TRL 5	TRL 7			5%		5%	
	Hybrid laminar flow on wing	AV-4	TRL 5	TRL 7						8%
	Laminar flow coating/riblets	AV-5	TRL 5	TRL 7			2%		2%	2%
	Low friction paint coating	AV-6	TRL 5	TRL 7	2%	2%		**2%**		
Aerodynamic Efficiency (Non-viscous)	Improved aero/transonic design	ANV-1	TRL 6	TRL 7	2%	2%	3%	2%	3%	4%
	Wingtip technologies (for fixed span)	ANV-2	TRL 9	TRL 9	1%	2%	2%	2%	2%	3%
	Variable camber with existing control	ANV-3	TRL 6	TRL 7	1%	1%	1%	1%	1%	1%
	Adaptive compliant trailing edge	ANV-4	TRL 5	TRL 6		1.50%	2%	1.50%	2%	2%
	Active stability control (reduced static)	ANV-5	TRL 4	TRL 6		1%	1%	1%	1%	1%
	Reduction of loads (active smart wing)	ANV-6	TRL 4	TRL 5	1.5%	1.5%	2%	1.5%	2%	3%
	Increased wing span	ANV-7	TRL 7	TRL 7	3%	3%	3%	3%	3%	3%
Structures, Materials and Manufacturing	1. All composite aircraft	S-0	TRL 8	TRL 9		10%	10%	10%	10%	10%
	1A. All composite fuselage	S-1	TRL 9	TRL 9	5%	5%	5%	5%	5%	5%
	1B. All composite wing	S-2	TRL 9	TRL 9	3%	3%	3%	3%	3%	3%
	1C. All composite nacelle	S-3	TRL 8	TRL 9	1%	1%	1%	1%	1%	1%
	1D. All composite empennage	S-4	TRL 9	TRL 9	1%	1%	1%	1%	1%	1%
	2. Integrated structural health monitoring	S-5	TRL 8	TRL 9		1%	2%	1%	2%	3%
	3. Advanced composite materials (higher strength, stiffness, toughness, damage tolerance, temperature)	S-6	TRL 5	TRL 9		2%	3%	2%	3%	4%
	4. Advanced airframe metal alloy (2000, 7000 series A1 alloy, 3rd gen A1-Li, higher temp, Ti, etc.)	S-7	TRL 8	TRL 9	1%	1%	1%	1%	1%	1%
	5. Advanced Manufacturing Technology									
	5A. Unitized construction (one piece fuselage barrel, wing box, skins, etc.)	S-8	TRL 8	TRL 9	3%	3%	4%	3%	4%	5%
	5B. Out of autoclave curing composites	S-9	TRL 5	TRL 8		1%	1%	1%	1%	1%
	5C. Automated tape laying, automated fiber placement	S-10	TRL 9	TRL 9	1%	1%	1%	1%	1%	1%
	5D. Composite sandwich construction	S-11	TRL 8	TRL 9		2%	2%	2%	2%	2%
	5E. Net shape components (forgings, castings, extrusions, RTM, RFI elimination of machining and fastening)	S-12	TRL 8	TRL 9	1%	1%	1%	1%	1%	1%

Single Aisle					2024			2034		
Technology Group	Technology	Code	Starting TRL	Est. TRL yr 2017 (Evol. Scenario)	Evol.	Mod.	Aggr.	Evol.	Mod.	Aggr.
	5F. Additive manufacturing (for mass customization of cabin interior structures, depot repairs, etc.)	S-13	TRL 5	TRL 7		1%	1%	1%	1%	1%
	5G. 3-D Preforms (aeroelastically tailored, braided, woven, stitched)	S-14								3%
	6. Bonded joints, innovations in structural joining	S-15	TRL 7	TRL 8		1%	1%	1%	1%	3%
	7. Damage tolerance concepts (3-D woven composites, PRSEUS, crack arrestment features, stitching, z pinning, etc.)	S-16	TRL 7	TRL 8		2%	2%	2%	2%	3%
	8. Adaptive and morphing structures (wings, control surfaces, etc.)	S-17	TRL 5	TRL 7						3%
	9. Advanced metallic joining (Friction Stir Welding, Advanced Welding)	S-18	TRL 8	TRL 9	1%	1%	1%	1%	1%	1%
	10. High temperature materials for Insulation, thermal protection	S-19	TRL 7	TRL 8		1%	1%	1%	1%	1%
	11. High temperature ceramics and coatings for engine components	S-20	TRL 6	TRL 8			1%		1%	1%
	12. Innovative load suppression, and vibration and aeromechanical stability control	S-21	TRL 6	TRL 7						1%
	13. Multifunctional materials and structures (noise cancellation, embedded sensors, signal processing, actuators, antenna, lightning strike, etc.)	S-22	TRL 5	TRL 7						1%
Aircraft Systems	More electric aircraft	Sys-1	TRL 9	TRL 9	1%	1%	1%	1%	1%	1%
	Electric landing-gear drive	Sys-2	TRL 4	TRL 5		1%	1%	1%	1%	1%

TABLE C-1B – STA CANDIDATE TECHNOLOGY LIST

Small Twin Aisle					2024			2034		
Technology Group	Technology	Code	Current TRL	Est. TRL yr 2017 (Evol. Scenario)	Evol.	Mod.	Aggr.	Evol.	Mod.	Aggr.
Aerodynamic Efficiency (Viscous) % Improvement values are in drag component, 100% deployment	Natural laminar flow on nacelles	AV-1	TRL 9	TRL 9	0.25%	0.5%	1%	0.5%	1%	1%
	Hybrid laminar flow on empennage	AV-2	TRL 4	TRL 6		2%	2%	2%	2%	2%
	Natural laminar flow on wings	AV-3	TRL 5	TRL 7						
	Hybrid laminar flow on wing	AV-4	TRL 5	TRL 7			10%		10%	10%
	Laminar flow coating/riblets	AV-5	TRL 5	TRL 7			2%		2%	2%
	Low friction paint coating	AV-6	TRL 5	TRL 7	2%	2%		2%		
Aerodynamic Efficiency (Non-viscous)	Improved aero/transonic design	ANV-1	TRL 6	TRL 7	2%	2%	3%	2%	3%	4%
	Wingtip technologies (for fixed span)	ANV-2	TRL 9	TRL 9	1%	2%	2%	2%	2%	3%
	Variable camber with existing control	ANV-3	TRL 6	TRL 7	1%	1%	1%	1%	1%	1%
	Adaptive compliant trailing edge	ANV-4	TRL 5	TRL 6		1.5%	2%	1.5%	2%	2%
	Active stability control (reduced static)	ANV-5	TRL 4	TRL 6		1%	1%	1%	1%	1%
	Reduction of loads (active smart wing)	ANV-6	TRL 3	TRL 5		1.5%	2%	1.5%	2%	3%
	Increased wing span	ANV-7	TRL 7	TRL 7			8%		8%	8%

Small Twin Aisle					2024			2034		
Technology Group	Technology	Code	Current TRL	Est. TRL yr 2017 (Evol. Scenario)	Evol.	Mod.	Aggr.	Evol.	Mod.	Aggr.
Structures, Materials and Manufacturing	1. All composite aircraft	S-0	TRL 8	TRL 9		10%	10%	10%	10%	10%
	1A. All composite fuselage	S-1	TRL 9	TRL 9	5%	5%	5%	5%	5%	5%
	1B. All composite wing	S-2	TRL 9	TRL 9	3%	3%	3%	3%	3%	3%
	1C. All composite nacelle	S-3	TRL 8	TRL 9	1%	1%	1%	1%	1%	1%
	1D. All composite empennage	S-4	TRL 9	TRL 9	1%	1%	1%	1%	1%	1%
	2. Integrated Structural Health Monitoring	S-5	TRL 8	TRL 9		1%	2%	1%	2%	3%
	3. Advanced composite materials (higher strength, stiffness, toughness, damage tolerance, temperature)	S-6	TRL 5	TRL 9		2%	3%	2%	3%	4%
	4. Advanced airframe metal alloy (2000, 7000 series A1 alloy, 3rd gen A1-Li, higher temp, Ti, etc.)	S-7	TRL 8	TRL 9	1%	1%	1%	1%	1%	1%
	5. Advanced Manufacturing Technology									
	5A. Unitized construction (one piece fuselage barrel, wing box, skins, etc.)	S-8	TRL 8	TRL 9	3%	3%	4%	3%	4%	5%
	5B. Out of autoclave curing composites	S-9	TRL 5	TRL 8		1%	1%	1%	1%	3%
	5C. Automated tape laying, automated fiber placement	S-10	TRL 9	TRL 9	1%	1%	1%	1%	1%	1%
	5D. Composite sandwich construction	S-11	TRL 8	TRL 9		2%	2%	2%	2%	2%
	5E. Net shape components (forgings, castings, extrusions, RTM, RFI elimination of machining and fastening)	S-12	TRL 8	TRL 9	1%	1%	1%	1%	1%	1%
	5F. Additive manufacturing (for mass customization of cabin interior structures, depot repairs, etc.)	S-13	TRL 5	TRL 7		1%	1%	1%	1%	2%
	5G. 3-D Preforms (aero elastically tailored, braided, woven, stitched)	S-14								3%
	6. Bonded joints, innovations in structural joining	S-15	TRL 7	TRL 8		1%	1%	1%	1%	3%
	7. Damage tolerance concepts (3-D woven composites, PRSEUS, crack arrestment features, stitching, z pinning, etc.)	S-16	TRL 7	TRL 8		2%	2%	2%	2%	3%
	8. Adaptive and morphing structures (wings, control surfaces, etc.)	S-17	TRL 5	TRL 7						3%
	9. Advanced metallic joining (Friction Stir Welding, Advanced Welding)	S-18	TRL 8	TRL 9	1%	1%	1%	1%	1%	1%
	10. High temperature materials for Insulation, thermal protection	S-19	TRL 7	TRL 8		1%	1%	1%	1%	1%
	11. High temperature ceramics and coatings for engine components	S-20	TRL 6	TRL 8			1%		1%	1%
	12. Innovative load suppression, and vibration and aeromechanical stability control	S-21	TRL 6	TRL 7						1%
	13. Multifunctional materials and structures (noise cancellation, embedded sensors, signal processing, actuators, antenna, lightning strike, etc.)	S-22	TRL 5	TRL 7						1%

Small Twin Aisle					2024			2034		
Technology Group	Technology	Code	Current TRL	Est. TRL yr 2017 (Evol. Scenario)	Evol.	Mod.	Aggr.	Evol.	Mod.	Aggr.
Aircraft Systems	More electric aircraft	Sys-1	TRL 9	TRL 9	1%	1%	1%	1%	1%	1%
	Electric landing-gear drive	Sys-2	TRL 3	TRL 5		1%	1%	1%	1%	1%

TABLE C-1C – RJ CANDIDATE TECHNOLOGY LIST

Regional Jet					2024			2034		
Technology Group	Technology	Code	Current TRL	Est. TRL yr 2017 (Evol. Scenario)	Evol.	Mod.	Aggr.	Evol.	Mod.	Aggr.
Aerodynamic Efficiency (Viscous) % Improvement values are in drag component, 100% deployment	Natural laminar flow on nacelles	AV-1	TRL 9	TRL 9	1%	1.3%	1.5%	1.3%	1.5%	1.5%
	Hybrid laminar flow on empennage	AV-2	TRL 4	TRL 6						
	Natural laminar flow on wings	AV-3	TRL 5	TRL 7			5%		5%	8%
	Hybrid laminar flow on wing	AV-4	TRL 5	TRL 7						
	Laminar flow coating/riblets	AV-5	TRL 5	TRL 7			2%		2%	2%
	Low friction paint coating	AV-6	TRL 5	TRL 7	2%	2%		2%		
Aerodynamic Efficiency (Non-viscous)	Improved aero/transonic design	ANV-1	TRL 6	TRL 7	2%	2%	3%	2%	3%	4%
	Wingtip technologies (for fixed span)	ANV-2	TRL 9	TRL 9	1%	2%	2%	2%	2%	3%
	Variable camber with existing control	ANV-3	TRL 6	TRL 7						
	Adaptive compliant trailing edge	ANV-4	TRL 5	TRL 6		1.5%	2%	1.5%	2%	2%
	Active stability control (reduced static)	ANV-5	TRL 4	TRL 6						
	Reduction of loads (active smart wing)	ANV-6	TRL 3	TRL 5						
	Increased wing span	ANV-7	TRL 7	TRL 7	1.5%	1.5%	1.5%	1.5	1.5%	1.5%
Structures, Materials and Manufacturing	1. All composite aircraft	S-0	TRL 8	TRL 9		9.5%	9.5%	9.5%	9.5%	9.5%
	1A. All composite fuselage	S-1	TRL 9	TRL 9	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%
	1B. All composite wing	S-2	TRL 9	TRL 9	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%
	1C. All composite nacelle	S-3	TRL 8	TRL 9	1%	1%	1%	1%	1%	1%
	1D. All composite empennage	S-4	TRL 9	TRL 9	1%	1%	1%	1%	1%	1%
	2. Integrated Structural Health Monitoring	S-5	TRL 8	TRL 9						
	3. Advanced composite materials (higher strength, stiffness, toughness, damage tolerance, temperature)	S-6	TRL 5	TRL 9		1.9%	2.9%	1.9%	2.9%	3.8%
	4. Advanced airframe metal alloy (2000, 7000 series A1 alloy, 3rd gen A1-Li, higher temp, Ti, etc.)	S-7	TRL 8	TRL 9	1%	1%	1%	1%	1%	1%
	5. Advanced Manufacturing Technology									
	5A. Unitized construction (one piece fuselage barrel, wing box, skins, etc.)	S-8	TRL 8	TRL 9	2.9%	2.9%	3.8%	2.9%	3.8%	4.8%
	5B. Out of autoclave curing composites	S-9	TRL 5	TRL 8		1%	1%	1%	1%	2.9%
	5C. Automated tape laying, automated fiber placement	S-10	TRL 9	TRL 9	1%	1%	1%	1%	1%	1%
	5D. Composite sandwich construction	S-11	TRL 8	TRL 9		1.9%	1.9%	1.9%	1.9%	1.9%
	5E. Net shape components (forgings, castings, extrusions, RTM, RFI elimination of machining and fastening)	S-12	TRL 8	TRL 9	1%	1%	1%	1%	1%	1%

Regional Jet					2024			2034		
Technology Group	Technology	Code	Current TRL	Est. TRL yr 2017 (Evol. Scenario)	Evol.	Mod.	Aggr.	Evol.	Mod.	Aggr.
	5F. Additive manufacturing (for mass customization of cabin interior structures, depot repairs, etc.)	S-13	TRL 5	TRL 7		1%	1%	1%	1%	1.9%
	5G. 3-D Preforms (aero elastically tailored, braided, woven, stitched)	S-14								2.9%
	6. Bonded joints, innovations in structural joining	S-15	TRL 7	TRL 8		1%	1%	1%	1%	2.9%
	7. Damage tolerance concepts (3-D woven composites, PRSEUS, crack arrestment features, stitching, z pinning, etc.)	S-16	TRL 7	TRL 8		1.9%	1.9%	1.9%	1.9%	2.9%
	8. Adaptive and morphing structures (wings, control surfaces, etc.)	S-17	TRL 5	TRL 7						
	9. Advanced metallic joining (Friction Stir Welding, Advanced Welding)	S-18	TRL 8	TRL 9	1%	1%	1%	1%	1%	1%
	10. High temperature materials for Insulation, thermal protection	S-19	TRL 7	TRL 8		1%	1%	1%	1%	1%
	11. High temperature ceramics and coatings for engine components	S-20	TRL 6	TRL 8			1%		1%	1%
	12. Innovative load suppression, and vibration and aeromechanical stability control	S-21	TRL 6	TRL 7						
	13. Multifunctional materials and structures (noise cancellation, embedded sensors, signal processing, actuators, antenna, lightning strike, etc.)	S-22	TRL 5	TRL 7						1%
Aircraft Systems	More electric aircraft	Sys-1	TRL 9	TRL 9	1%	1%	1%	1%	1%	1%
	Electric landing-gear drive	Sys-2	TRL 3	TRL 5		0.5%	0.5%	0.5%	0.5%	0.5%

APPENDIX D—Engine Technology Component Matrix

The engine technology component matrix below captures the TRL based on known breadboard and prototype testing thru technology demonstration relevant to each scenario for the three aircraft configurations. Both the SA 2034 Aggressive and RJ 2034 Aggressive include Open Rotor engine designs and performance estimates. Tables D-1 through D-3 provides summaries of the GasTurb modeled results for each engine in the Technology Deployment scenarios, as well as the candidate technologies employed. There is a table for each aircraft class.

TABLE D-1 – SA TECHNOLOGY COMPONENT MATRIX

	2024 Single Aisle						2034 Single Aisle					
Tech.	TRL Est	Evol.	TRL Est	Mod.	TRL Est	Aggressive	TRL Est	Evol.	TRL Est	Mod.	TRL Est	Aggressive (OR)
GasTurb Modeling		Modeled New Engine (2024)		Interpolated Inputs		2034 New Engine		2024 Stretch Inputs		Modeled New Engine (2034)		Modeled OR Engine
TSFC reduction		15.3%		17.5%		19.6%		17.5%		19.6%		26.6%
Fan PR		1.4		1.4		1.3		1.4		1.3		Not Applicable **
BPR		11-12		11-12		16-17		11-12		16-17		Not Applicable **
OPR		45		45		52		45		52		52
RIT		+120 to +160 F		+120 to +160 F		+270 to +300 F		+120 to +160 F		+270 to +300 F		+270 to +300 F
T3		+80 to +90 F		+80 to +90 F		+130 to +140 F		+80 to +90 F		+130 to +140 F		+130 to +140 F
Fan	7	Low AR Shroudless	7	Low AR Shroudless	5	Very Low Tip Speed	7	Low AR Shroudless	5	Very Low Tip Speed		Not Applicable **
	7	Swept 3-D Aero	7	Swept 3-D Aero	5	Lightweight Blades	7	Swept 3-D Aero	5	Lightweight Blades		Not Applicable **
	7	Lower Tip Speed	7	Lower Tip Speed	5	Swept 3-D Aero	7	Lower Tip Speed	5	Swept 3-D Aero		Not Applicable **
	7	Lightweight Blades	7	Lightweight Blades	4	Extensive Use of Composites in Case	7	Lightweight Blades	4	Extensive Use of Composites in Case		Not Applicable **
	7	Composite Cases	7	Composite Cases			7	Composite Cases				Not Applicable **
HPC	7	Adv 3-D Aero	7	Adv 3-D Aero	5	Adv 3-D Aero	7	Adv 3-D Aero	5	Adv 3-D Aero	5	Adv 3-D Aero
	7	Integrally Bladed Rotors	7	Integrally Bladed Rotors	5	Integrally Bladed Rotors	7	Integrally Bladed Rotors	5	Integrally Bladed Rotors	5	Integrally Bladed Rotors
	7	Powder Ni Aft Stgs	7	Powder Ni Aft Stgs	5	Adv Power Ni	7	Powder Ni Aft Stgs	5	Adv Power Ni	5	Adv Power Ni
Combustor	7	Low Nox Features to Accom-modate Higher OPR/T3	7	Low Nox Features to Accommodate Higher OPR/T3	5	Low Nox Features	7	Low Nox Features to Accommodate Higher OPR/T3	5	Low Nox Features	5	Low Nox Features
HPT	7	Adv Cast Ni Airfoils	5	Adv Cast Ni Airfoils	4	Impr Cast Ni A/Fs	5	Adv Cast Ni Airfoils	4	Impr Cast Ni A/Fs	4	Impr Cast Ni A/Fs
	7	Adv Film Cooling	5	Adv Film Cooling	4	Impr Adv Cooling	5	Adv Film Cooling	4	Impr Adv Cooling	4	Impr Adv Cooling
	7	Adv TBCs	5	Adv TBCs	4	Impr Adv TBCs	5	Adv TBCs	4	Impr Adv TBCs	4	Impr Adv TBCs
	5	CMC Static Seals(1)	5	CMC Static Seals	4	CMC Static Parts	5	CMC Static Seals	4	CMC Static Parts	4	CMC Static Parts
LPT	7	High Speed LPT(1)	5	High Speed LPT	5	High Speed LPT	5	High Speed LPT	5	High Speed LPT	5	High Speed LPT
	5	Ti/Al Blades(1)	5	Ti/Al Blades	5	Ti/Al Blades	5	Ti/Al Blades	5	Ti/Al Blades	5	Ti/Al Blades

	2024 Single Aisle						2034 Single Aisle					
Tech.	TRL Est	Evol.	TRL Est	Mod.	TRL Est	Aggressive	TRL Est	Evol.	TRL Est	Mod.	TRL Est	Aggressive (OR)
	5	CMC Static Seals(1)	5	CMC Static Seals	5	CMC Static Seals	5	CMC Static Seals	5	CMC Static Seals	5	CMC Static Seals
Nozzles	7	Variable Area Nozzle (Optional)	7	Variable Area Nozzle (Optional)	5	Variable Area Nozzle	7	Variable Area Nozzle (Optional)	5	Variable Area Nozzle		Not Applicable
Inlets	7	Low Drag, Lightweight Nacelles	7	Low Drag, Lightweight Nacelles	5	Adv Low Drag, Lightweight Nacelles	7	Low Drag, Lightweight Nacelles	5	Adv Low Drag, Lightweight Nacelles		Not Applicable
GTF	7	Optional (1)	7	Included	5	Higher Gear Ratio	7	Included	5	Higher Gear Ratio		Not Applicable
Thrust/Wt (lbs)		**4.6**		**4.7(2)**		**4.5**		**4.7(2)**		**4.5**		**(2)**

(1) GTF option incorporates high speed LPT, but not CMC static seals nor Ti/Al blades Direct drive option incorporates CMC static seals and Ti/Al blades, but not high speed LPT.
(2) Fuel Burn benefit for 2024 Stretch and 2034 Evolutionary was an interpolated value. Presumption made that benefit was 50% weight and 50% TSFC relative to 2024 Evolutionary Single Aisle to calculate Fn/Wt.
(3) Uncertainties surrounding weight for Open Rotor precluded Fn/Wt estimate.
** Note: Open Rotor (OR) performance was bounded by using gas generator efficiencies consistent with those of the 2034 Stretch GTF and evaluating engine performance with propeller efficiencies of 80-85% at Mach Numbers of 0.75 and 0.80.

TABLE D-2 – STA TECHNOLOGY COMPONENT MATRIX

	2024 Small Twin Aisle						2034 Small Twin Aisle					
Tech.	TRL Est	Evol.	TRL Est	Mod.	TRL Est	Aggressive	TRL Est	Evol.	TRL Est	Mod.	TRL Est	Aggressive (OR)
GasTurb Modeling		Modeled New Engine (2024)		Interpolated Inputs		Modeled New Engine (2034)		2024 Stretch Input		Modeled New Engine (2034)		Interpolated TSFC – 2% improvement
TSFC reduction		6.0%		10.0%		13.9%		10.0%		13.9%		15.9%
Fan PR		1.5		1.4		1.3		1.4		1.3		1.3
BPR		9-10		12-13		18-19		12-13		18-19		18-19
OPR		48		48		55		48		55		55
RIT		+120 to +160 F		+120 to +160 F		+270 to +300 F		+120 to +160 F		+270 to +300 F		+270 to +300 F
T3		+80 to +90 F		+80 to +90 F		+130 to +140 F		+80 to +90 F		+130 to +140 F		+130 to +140 F
Fan	8	Low AR Shroudless	6	Low AR Shroudless	5	Very Low Tip Speed	6	Low AR Shroudless	5	Very Low Tip Speed	5	Very Low Tip Speed
	8	Swept 3-D Aero	6	Swept 3-D Aero	5	Lightweight Blades	6	Swept 3-D Aero	5	Lightweight Blades	5	Lightweight Blades
			6	Lower Tip Speed	5	Swept 3-D Aero	6	Lower Tip Speed	5	Swept 3-D Aero	5	Swept 3-D Aero
	8	Lightweight Blades	6	Lightweight Blades	4	Extensive Use of Composites in Case	6	Lightweight Blades	4	Extensive Use of Composites in Case	4	Extensive Use of Composites in Case
	8	Composite Cases	6	Composite Cases			6	Composite Cases				
HPC	8	Adv 3-D Aero	6	Adv 3-D Aero	5	Adv 3-D Aero	6	Adv 3-D Aero	5	Adv 3-D Aero	5	Adv 3-D Aero
	8	Integrally Bladed Rotors	6	Integrally Bladed Rotors	5	Integrally Bladed Rotors	6	Integrally Bladed Rotors	5	Integrally Bladed Rotors	5	Integrally Bladed Rotors
	8	Powder Ni Aft Stgs	6	Powder Ni Aft Stgs	5	Adv Power Ni	6	Powder Ni Aft Stgs	5	Adv Power Ni	5	Adv Power Ni
Combustor	8	Low Nox Features to Accommodate Higher OPR/T3	6	Low Nox Features to Accommodate Higher OPR/T3	5	Low Nox Features	6	Low Nox Features to Accommodate Higher OPR/T3	5	Adv Low Nox Features	5	Adv Low Nox Features
HPT	8	Adv Cast Ni Airfoils	5	Adv Cast Ni Airfoils	4	Impr Cast Ni A/Fs	5	Adv Cast Ni Airfoils	4	Impr Cast Ni A/Fs	4	Impr Cast Ni A/Fs

2024 Small Twin Aisle							2034 Small Twin Aisle					
Tech.	TRL Est	Evol.	TRL Est	Mod.	TRL Est	Aggressive	TRL Est	Evol.	TRL Est	Mod.	TRL Est	Aggressive (OR)
	8	Adv Film Cooling	5	Adv Film Cooling	4	Impr Adv Cooling	5	Adv Film Cooling	4	Impr Adv Cooling	4	Impr Adv Cooling
	8	Adv TBCs	5	Adv TBCs	4	Impr Adv TBCs	5	Adv TBCs	4	Impr Adv TBCs	4	Impr Adv TBCs
			5	CMC Static Seals(1)	4	CMC Static Parts	5	CMC Static Seals(1)	4	CMC Static Parts	4	CMC Static Parts
LPT			5	High Speed LPT(1)	5	High Speed LPT	5	High Speed LPT(1)	5	High Speed LPT	5	High Speed LPT
			5	Ti/Al Blades(1)	5	Ti/Al Blades	5	Ti/Al Blades(1)	5	Ti/Al Blades	5	Ti/Al Blades
			5	CMC Static Seals(1)	5	CMC Static Seals	5	CMC Static Seals(1)	5	CMC Static Seals	5	CMC Static Seals
Nozzles			6	Variable Area Nozzle	5	Variable Area Nozzle	6	Variable Area Nozzle (Optional)	5	Variable Area Nozzle	5	Variable Area Nozzle
Inlets			6	Low Drag, Lightweight Nacelles	5	Adv Low Drag, Lightweight Nacelles	6	Low Drag, Lightweight Nacelles	5	Adv Low Drag, Lightweight Nacelles	5	Adv Low Drag, Lightweight Nacelles
GTF			5	Optional(1)	5	Higher Gear Ratio	6	Optional(1)	5	Higher Gear Ratio	5	Higher Gear Ratio
Thrust/Wt (lbs)		**4.8**		**4.5**		**4.3**		**4.5**		**4.3**		**4.6**

(1) GTF option incorporates high speed LPT, but not CMC static seals nor Ti/Al blades Direct drive option incorporates CMC static seals and Ti/Al blades, but not high speed LPT.
(2) Fuel Burn benefit for 2024 Stretch and 2034 Evolutionary was an interpolated value. Presumption made that benefit was 50% weight and 50% TSFC relative to 2024 Evolutionary Single Aisle to calculate Fn/Wt.
(3) The Aggressive Scenario for 2034 Twin Aisle was judged to be 'beyond the headlights'. A 2% improvement in fuel burn was presumed to be achieved in that time frame relative to the Stretch 2034 Twin Aisle. Technologies shown in this column are a copy of those shown for the Stretch. Fn/Wt value shown presumes that this fuel burn improvement was 50% TSFC and 50% weight.

TABLE D-3 – RJ TECHNOLOGY COMPONENT MATRIX

2024 Regional Jet							2034 Regional Jet					
Tech.	TRL Est	Evol.	TRL Est	Mod.	TRL Est	Aggressive	TRL Est	Evol.	TRL Est	Mod.	TRL Est	Aggressive (OR)
GasTurb Modeling		Modeled New Engine (2024)		Interpolated Inputs		2034 New Engine		2024 Stretch Inputs		Modeled New Engine (2034)		Modeled OR Engine
TSFC reduction		17.0%		19.0%		21.0%		19.0%		21.0%		26.8%
Fan PR		1.44		1.4		1.4		1.4		1.4		Not Applicable **
BPR		9-10		11-12		11-12		12-13		11-12		Not Applicable **
OPR		31		45		45		45		45		52
RIT		+120 to +160 F		+120 to +160 F		+120 to +160 F		+120 to +160 F		+120 to +160 F		+270 to +300 F
T3				+80 to +90 F		+80 to +90 F		+80 to +90 F		+80 to +90 F		+130 to +140 F
Fan	7	Low AR Shroudless	7	Low AR Shroudless	7	Very Low Tip Speed	7	Low AR Shroudless	7	Low AR Shroudless	N/A **	
	7	Swept 3-D Aero	7	Swept 3-D Aero	7	Swept 3-D Aero	7	Swept 3-D Aero	7	Swept 3-D Aero		Not Applicable **
	7	Lower Tip Speed	7	Lower Tip Speed	7	Lower Tip Speed	7	Lower Tip Speed	7	Lower Tip Speed		Not Applicable **
	7	Lightweight Blades	7	Lightweight Blades	7	Lightweight Blades	7	Lightweight Blades	7	Lightweight Blades		Not Applicable **
	7	Composite Cases	7	Composite Cases	7	Composite Cases	7	Composite Cases	7	Composite Cases		Not Applicable **
HPC	7	Adv 3-D Aero	7	Adv 3-D Aero	7	Adv 3-D Aero	7	Adv 3-D Aero	7	Adv 3-D Aero	5	Adv 3-D Aero

	2024 Regional Jet						2034 Regional Jet					
Tech.	TRL Est	Evol.	TRL Est	Mod.	TRL Est	Aggressive	TRL Est	Evol.	TRL Est	Mod.	TRL Est	Aggressive (OR)
	7	Integrally Bladed Rotors	7	Integrally Bladed Rotors	7	Integrally Bladed Rotors	7	Integrally Bladed Rotors	7	Integrally Bladed Rotors	5	Integrally Bladed Rotors
			7	Powder Ni Aft Stgs	7	Powder Ni Aft Stgs	7	Powder Ni Aft Stgs	7	Powder Ni Aft Stgs	5	Adv Power Ni
Combustor			7	Low Nox Features to Accommodate Higher OPR/T3	7	Low Nox Features to Accommodate Higher OPR/T3	7	Low Nox Features to Accommodate Higher OPR/T3	7	Low Nox Features to Accommodate Higher OPR/T3	5	Low Nox Features
HPT	7	Adv Cast Ni Airfoils	7	Adv Cast Ni Airfoils	5	Impr Cast Ni A/Fs	7	Adv Cast Ni Airfoils	5	Impr Cast Ni A/Fs	4	Impr Cast Ni A/Fs
	7	Adv Film Cooling	7	Adv Film Cooling	5	Impr Adv Cooling	7	Adv Film Cooling	5	Impr Adv Cooling	4	Impr Adv Cooling
	7	Adv TBCs	7	Adv TBCs	5	Impr Adv TBCs	7	Adv TBCs	4	Impr Adv TBCs	4	Impr Adv TBCs
					5	CMC Static Seals			5	CMC Static Seals	4	CMC Static Parts
LPT	7	High Speed LPT	7	High Speed LPT	5	High Speed LPT	7	High Speed LPT	5	High Speed LPT	5	High Speed LPT
					5	Ti/Al Blades			5	Ti/Al Blades	5	Ti/Al Blades
					5	CMC Static Seals			5	CMC Static Seals	5	CMC Static Seals
Nozzles	8	Fixed Nozzle	8	Fixed Nozzle	8	Fixed Nozzle	8	Fixed Nozzle	8	Fixed Nozzle		Not Applicable
Inlets	7	Low Drag, Lightweight Nacelles	7	Low Drag, Lightweight Nacelles	7	Low Drag, Lightweight Nacelles	7	Low Drag, Lightweight Nacelles	7	Low Drag, Lightweight Nacelles		Not Applicable
GTF	7	Included	7	Included	7	Included	7	Included	7	Included		Not Applicable
Thrust/Wt (lbs)		**4.8**		**4.5**		**4.3**		**4.5**		**4.3**		**4.6**

(1) GTF option incorporates high speed LPT, but not CMC static seals nor Ti/Al blades Direct drive option incorporates CMC static seals and Ti/Al blades, but not high speed LPT.
(2) Fuel Burn benefit for 2024 Stretch and 2034 Evolutionary was an interpolated value. Presumption made that benefit was 50% weight and 50% TSFC relative to 2024 Evolutionary Single Aisle to calculate Fn/Wt.
(3) Uncertainties surrounding weight for Open Rotor precluded Fn/Wt estimate.

APPENDIX E—Subsystem Improvements

The data contained in this appendix detailed the summary results of the Technical SME's evaluation of the varying technologies assessed in the study. For each technology candidate a forecasted improvement was identified for each of the Technology Deployment scenarios for each aircraft class. The improvements were dependent on the area assessed. Improvements for Aerodynamic (Viscous and Non-Viscous) Efficiency are in terms of reduction in drag. Improvements for Structural items are in terms of weight reduction. Improvements for Systems are in terms of fuel efficiency improvement. In this appendix is a table for each technology grouping (e.g., Aerodynamic Viscous, Structures and Materials, etc.) for each aircraft type (Single-Aisle, Small Twin Aisle, and Regional Jet).

Single-Aisle Evaluations

TABLE E-1 – SA AERODYNAMIC VISCOUS TECHNOLOGIES

Technology Acronym	Technology Subsystem Description	SA 2024			SA 2034		
		TP-A	TP-B	TP-C	TP-B'	TP-C'	TP-D
Title		Evol.	Mod	Aggr	Evol	Mode	Aggr
Aerodynamic Efficiency (Viscous)							
AV-1	Natural laminar flow on nacelles	Yes	Yes	Yes	Yes	Yes	Yes
	Natural laminar flow on nacelles (calculated)	1.0%	1.3%	1.5%	1.3%	1.5%	1.5%
AV-2	Hybrid laminar flow on empennage	No	Yes	Yes	Yes	Yes	Yes
	Hybrid laminar flow on empennage (calculated)		2.0%	2.0%	2.0%	2.0%	2.0%
AV-3	Natural laminar flow on wings	No	No	Yes	No	Yes	No
	Natural laminar flow on wings (calculated)			5.0%		5.0%	
AV-4	Hybrid laminar flow on wing	No	No	No	No	No	Yes
	Hybrid laminar flow on wing (calculated)						8.0%
AV-5	Laminar flow coating/riblets	No	No	Yes	No	Yes	Yes
	Laminar flow coating/riblets (calculated)			2.0%		2.0%	2.0%
AV-6	Low friction paint coating	Yes	Yes	No	Yes	No	No
	Low friction paint coating (calculated)	2.0%	2.0%		2.0%		
	Total Aerodynamic Efficiency (Viscous) Improvement	3.0%	5.3%	10.5%	5.3%	10.5%	13.5%

TABLE E-2 – SA AERODYNAMIC NON-VISCOUS TECHNOLOGIES

Technology Acronym	Technology Subsystem Description	SA 2024			SA 2034		
		TP-A	TP-B	TP-C	TP-B'	TP-C'	TP-D
Title		Evol.	Mod	Aggr	Evol	Mode	Aggr
Aerodynamic Efficiency (Non-Viscous)							
ANV-1	Improved aero/transonic design	Yes	Yes	Yes	Yes	Yes	Yes
	Improved aero/transonic design (calculated)	2.0%	2.0%	3.0%	2.0%	3.0%	4.0%
ANV-2	Wingtip technologies (for fixed span)	Yes	Yes	Yes	Yes	Yes	Yes
	Wingtip technologies (for fixed span) (calculated)	1.0%	2.0%	2.0%	2.0%	2.0%	3.0%
ANV-3	Variable camber with existing control surfaces	Yes	Yes	Yes	Yes	Yes	Yes
	Variable camber with existing control surfaces (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
ANV-4	Adaptive compliant trailing edge	No	Yes	Yes	Yes	Yes	Yes
	Adaptive compliant trailing edge (calculated)		1.5%	2.0%	1.5%	2.0%	2.0%

Technology Acronym	Technology Subsystem Description	SA 2024			SA 2034		
		TP-A	TP-B	TP-C	TP-B'	TP-C'	TP-D
Title		Evol.	Mod	Aggr	Evol	Mode	Aggr
ANV-5	Active stability control (reduced static margin)	No	Yes	Yes	Yes	Yes	Yes
	Active stability control (reduced static margin) (calculated)		1.0%	1.0%	1.0%	1.0%	1.0%
ANV-6	Reduction of loads (active smart wings)	No	Yes	Yes	Yes	Yes	Yes
	Reduction of loads (active smart wings) (calculated)		1.5%	2.0%	1.5%	2.0%	3.0%
ANV-7	Increased wing span	Yes	Yes	Yes	Yes	Yes	Yes
	Increased wing span (calculated)	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
	Total Aerodynamic Efficiency (Non-Viscous) Improvement	7.0%	12.0%	14.0%	12.0%	14.0%	17.0%

TABLE E-3 – SA STRUCTURAL TECHNOLOGIES

Technology Acronym	Technology Subsystem Description	SA 2024			SA 2034		
		TP-A	TP-B	TP-C	TP-B'	TP-C'	TP-D
Title		Evol.	Mod	Aggr	Evol	Mode	Aggr
Structural Weight							
S-1	1A. All composite fuselage	Yes	Yes	Yes	Yes	Yes	Yes
	1A. All composite fuselage (calculated)	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
S-2	1B. All composite wing	Yes	Yes	Yes	Yes	Yes	Yes
	1B. All composite wing (calculated)	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
S-3	1C. All composite nacelle	Yes	Yes	Yes	Yes	Yes	Yes
	1C. All composite nacelle (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-4	1D. All composite empennage	Yes	Yes	Yes	Yes	Yes	Yes
	1D. All composite empennage (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-5	2. Integrated structural health monitoring	No	Yes	Yes	Yes	Yes	Yes
	2. Integrated structural health monitoring (calculated)		1.0%	2.0%	1.0%	2.0%	3.0%
S-6	3. Advanced composite materials (higher strength, stiffness, toughness, damage tolerance, temperature)	No	Yes	Yes	Yes	Yes	Yes
	3. Advanced composite materials (higher strength, stiffness, toughness, damage tolerance, temperature) (calculated)		2.0%	3.0%	2.0%	3.0%	4.0%
S-7	4. Advanced airframe metal alloy (2000, 7000 series Al alloy, 3rd gen Al-Li, higher temp Ti, etc.)	Yes	Yes	Yes	Yes	Yes	Yes
	4. Advanced airframe metal alloy (2000, 7000 series Al alloy, 3rd gen Al-Li, higher temp Ti, etc.) (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-8	5A. Unitized construction (one piece fuselage barrel, wing box, skins, etc.)	Yes	Yes	Yes	Yes	Yes	Yes
	5A. Unitized construction (one piece fuselage barrel, wing box, skins, etc.) (calculated)	3.0%	3.0%	4.0%	3.0%	4.0%	5.0%
S-9	5B. Out of autoclave curing composites	No	Yes	Yes	Yes	Yes	Yes
	5B. Out of autoclave curing composites (calculated)		1.0%	1.0%	1.0%	1.0%	3.0%
S-10	5C. Automated tape laying, automated fiber placement	Yes	Yes	Yes	Yes	Yes	Yes
	5C. Automated tape laying, automated fiber placement (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-11	5D. Composite sandwich construction	No	Yes	Yes	Yes	Yes	Yes
	5D. Composite sandwich construction (calculated)		2.0%	2.0%	2.0%	2.0%	2.0%
S-12	5E. Net shape components (forgings, castings, extrusions, RTM, RFI elimination of machining and fastening)	Yes	Yes	Yes	Yes	Yes	Yes

Technology Acronym	Technology Subsystem Description	SA 2024			SA 2034		
		TP-A	TP-B	TP-C	TP-B'	TP-C'	TP-D
Title		Evol.	Mod	Aggr	Evol	Mode	Aggr
	5E. Net shape components (forgings, castings, extrusions, RTM, RFI elimination of machining and fastening) (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-13	5F. Additive manufacturing (for mass customization of cabin interior structures, depot repairs, etc.)	No	Yes	Yes	Yes	Yes	Yes
	5F. Additive manufacturing (for mass customization of cabin interior structures, depot repairs, etc.) (calculated)		1.0%	1.0%	1.0%	1.0%	2.0%
S-14	5G. 3-D Preforms (aero elastically tailored, braided, woven, stitched)	No	No	No	No	No	Yes
	5G. 3-D Preforms (aero elastically tailored, braided, woven, stitched) (calculated)						3.0%
S-15	6. Bonded joints, Innovations in structural joining	No	Yes	Yes	Yes	Yes	Yes
	6. Bonded joints, Innovations in structural joining (calculated)		1.0%	1.0%	1.0%	1.0%	3.0%
S-16	7. Damage tolerance concepts (3-D woven composites, PRSEUS, crack arrestment features, stitching, z pinning, etc.)	No	Yes	Yes	Yes	Yes	Yes
	7. Damage tolerance concepts (3-D woven composites, PRSEUS, crack arrestment features, stitching, z pinning, etc.) (calculated)		2.0%	2.0%	2.0%	2.0%	3.0%
S-17	8. Adaptive and morphing structures (wings, control surfaces, etc.)	No	No	No	No	No	Yes
	8. Adaptive and morphing structures (wings, control surfaces, etc.) (calculated)						3.0%
S-18	9. Advanced metallic joining (Friction Stir Welding, Advanced Welding)	Yes	Yes	Yes	Yes	Yes	Yes
	9. Advanced metallic joining (Friction Stir Welding, Advanced Welding) (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-19	10. High temperature materials for Insulation, thermal protection	No	Yes	Yes	Yes	Yes	Yes
	10. High temperature materials for Insulation, thermal protection (calculated)		1.0%	1.0%	1.0%	1.0%	1.0%
S-20	11. High temperature ceramics and coatings for engine components	No	No	Yes	No	Yes	Yes
	11. High temperature ceramics and coatings for engine components (calculated)			1.0%		1.0%	1.0%
S-21	12. Innovative load suppression, and vibration and aeromechanical stability control	No	No	No	No	No	Yes
	12. Innovative load suppression, and vibration and aeromechanical stability control (calculated)						1.0%
S-22	13. Multifunctional materials and structures (noise cancellation, embedded sensors, signal processing, actuators, antenna, lightning strike, etc.)	No	No	No	No	No	Yes
	13. Multifunctional materials and structures (noise cancellation, embedded sensors, signal processing, actuators, antenna, lightning strike, etc.) (calculated)						1.0%
	Total Structural Weight Improvement	17.0%	28.0%	32.0%	28.0%	32.0%	49.0%

TABLE E-4 – SA SYSTEM AND CONFIGURATION TECHNOLOGIES

Technology Acronym / Title	Technology Subsystem Description	SA 2024 TP-A Evol.	SA 2024 TP-B Mod	SA 2024 TP-C Aggr	SA 2034 TP-B' Evol	SA 2034 TP-C' Mode	SA 2034 TP-D Aggr
Aircraft Systems							
Sys-1	More electric aircraft	Yes	Yes	Yes	Yes	Yes	Yes
	More electric aircraft (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Sys-2	Electric landing-gear drive	No	Yes	Yes	Yes	Yes	Yes
	Electric landing-gear drive (calculated)		0.5%	0.5%	0.5%	0.5%	0.5%
	Total Aircraft Systems Improvement	1.0%	1.5%	1.5%	1.5%	1.5%	1.5%

TABLE E-5 – SA ENGINE CONFIGURATIONS

Technology Acronym / Title	Technology Subsystem Description	SA 2024 TP-A Evol.	SA 2024 TP-B Mod	SA 2024 TP-C Aggr	SA 2034 TP-B' Evol	SA 2034 TP-C' Mode	SA 2034 TP-D Aggr
Engine Configuration		SA2024NE	SA2024 Stretch	SA2034NE	SA2024 Stretch	SA2034NE	SA2034NE
TSFC Performance Calculation	TSFC Improvement	15.3%	17.5%	19.5%	17.5%	19.6%	21.6%

Small Twin Aisle Evaluations

TABLE E-6 – STA AERODYNAMIC VISCOUS TECHNOLOGIES

Technology Acronym / Title	Technology Subsystem Description	STA 2024 TP-A Evol.	STA 2024 TP-B Mod	STA 2024 TP-C Aggr	STA 2034 TP-B' Evol	STA 2034 TP-C' Mode	STA 2034 TP-D Aggr
Aerodynamic Efficiency (Viscous)							
AV-1	Natural laminar flow on nacelles	Yes	Yes	Yes	Yes	Yes	Yes
	Natural laminar flow on nacelles (calculated)	0.3%	0.5%	1.0%	0.5%	1.0%	1.0%
AV-2	Hybrid laminar flow on empennage	No	Yes	Yes	Yes	Yes	Yes
	Hybrid laminar flow on empennage (calculated)		2.0%	2.0%	2.0%	2.0%	2.0%
AV-3	Natural laminar flow on wings	No	No	No	No	No	No
	Natural laminar flow on wings (calculated)						
AV-4	Hybrid laminar flow on wing	No	No	Yes	No	Yes	Yes
	Hybrid laminar flow on wing (calculated)			10.0%		10.0%	10.0%
AV-5	Laminar flow coating/riblets	No	No	Yes	No	Yes	Yes
	Laminar flow coating/riblets (calculated)			2.0%		2.0%	2.0%
AV-6	Low friction paint coating	Yes	Yes	No	Yes	No	No
	Low friction paint coating (calculated)	2.0%	2.0%		2.0%		
	Total Aerodynamic Efficiency (Viscous) Improvement	2.3%	4.5%	15.0%	4.5%	15.0%	15.0%

TABLE E-7 – STA AERODYNAMIC NON-VISCOUS TECHNOLOGIES

Technology Acronym / Title	Technology Subsystem Description	STA 2024 TP-A Evol.	STA 2024 TP-B Mod	STA 2024 TP-C Aggr	STA 2034 TP-B' Evol	STA 2034 TP-C' Mode	STA 2034 TP-D Aggr
Aerodynamic Efficiency (Non-Viscous)							
ANV-1	Improved aero/transonic design	Yes	Yes	Yes	Yes	Yes	Yes
	Improved aero/transonic design (calculated)	2.0%	2.0%	3.0%	2.0%	3.0%	4.0%
ANV-2	Wingtip technologies (for fixed span)	Yes	Yes	Yes	Yes	Yes	Yes
	Wingtip technologies (for fixed span) (calculated)	1.0%	2.0%	2.0%	2.0%	2.0%	3.0%

Technology Acronym / Title	Technology Subsystem Description	STA 2024			STA 2034		
		TP-A	TP-B	TP-C	TP-B'	TP-C'	TP-D
		Evol.	Mod	Aggr	Evol	Mode	Aggr
ANV-3	Variable camber with existing control surfaces	Yes	Yes	Yes	Yes	Yes	Yes
	Variable camber with existing control surfaces (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
ANV-4	Adaptive compliant trailing edge	No	Yes	Yes	Yes	Yes	Yes
	Adaptive compliant trailing edge (calculated)		1.5%	2.0%	1.5%	2.0%	2.0%
ANV-5	Active stability control (reduced static margin)	No	Yes	Yes	Yes	Yes	Yes
	Active stability control (reduced static margin) (calculated)		1.0%	1.0%	1.0%	1.0%	1.0%
ANV-6	Reduction of loads (active smart wings)	No	Yes	Yes	Yes	Yes	Yes
	Reduction of loads (active smart wings) (calculated)		1.5%	2.0%	1.5%	2.0%	3.0%
ANV-7	Increased wing span	No	No	Yes	No	Yes	Yes
	Increased wing span (calculated)			8.0%		8.0%	8.0%
	Total Aerodynamic Efficiency (Non-Viscous) Improvement	4.0%	9.0%	19.0%	9.0%	19.0%	22.0%

TABLE E-8 – STA STRUCTURAL TECHNOLOGIES

Technology Acronym / Title	Technology Subsystem Description	STA 2024			STA 2034		
		TP-A	TP-B	TP-C	TP-B'	TP-C'	TP-D
		Evol.	Mod	Aggr	Evol	Mode	Aggr
Structural Weight							
S-1	1A. All composite fuselage	Yes	Yes	Yes	Yes	Yes	Yes
	1A. All composite fuselage (calculated)	5.0%	5.0%	5.0%	5.0%	5.0%	5.0%
S-2	1B. All composite wing	Yes	Yes	Yes	Yes	Yes	Yes
	1B. All composite wing (calculated)	3.0%	3.0%	3.0%	3.0%	3.0%	3.0%
S-3	1C. All composite nacelle	Yes	Yes	Yes	Yes	Yes	Yes
	1C. All composite nacelle (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-4	1D. All composite empennage	Yes	Yes	Yes	Yes	Yes	Yes
	1D. All composite empennage (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-5	2. Integrated structural health monitoring	No	Yes	Yes	Yes	Yes	Yes
	2. Integrated structural health monitoring (calculated)		1.0%	2.0%	1.0%	2.0%	3.0%
S-6	3. Advanced composite materials (higher strength, stiffness, toughness, damage tolerance, temperature)	No	Yes	Yes	Yes	Yes	Yes
	3. Advanced composite materials (higher strength, stiffness, toughness, damage tolerance, temperature) (calculated)		2.0%	3.0%	2.0%	3.0%	4.0%
S-7	4. Advanced airframe metal alloy (2000, 7000 series Al alloy, 3rd gen Al-Li, higher temp Ti, etc.)	Yes	Yes	Yes	Yes	Yes	Yes
	4. Advanced airframe metal alloy (2000, 7000 series Al alloy, 3rd gen Al- temp Ti, etc.) (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-8	5A. Unitized construction (one piece fuselage barrel, wing box, skins, etc.)	Yes	Yes	Yes	Yes	Yes	Yes
	5A. Unitized construction (one piece fuselage barrel, wing box, skins, etc.) (calculated)	3.0%	3.0%	4.0%	3.0%	4.0%	5.0%
S-9	5B. Out of autoclave curing composites	No	Yes	Yes	Yes	Yes	Yes
	5B. Out of autoclave curing composites (calculated)		1.0%	1.0%	1.0%	1.0%	3.0%
S-10	5C. Automated tape laying, automated fiber placement	Yes	Yes	Yes	Yes	Yes	Yes

Technology Acronym Title	Technology Subsystem Description	STA 2024 TP-A Evol.	STA 2024 TP-B Mod	STA 2024 TP-C Aggr	STA 2034 TP-B' Evol	STA 2034 TP-C' Mode	STA 2034 TP-D Aggr
	5C. Automated tape laying, automated fiber placement (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-11	5D. Composite sandwich construction	No	Yes	Yes	Yes	Yes	Yes
	5D. Composite sandwich construction (calculated)		2.0%	2.0%	2.0%	2.0%	2.0%
S-12	5E. Net shape components (forgings, castings, extrusions, RTM, RFI elimination of machining and fastening)	Yes	Yes	Yes	Yes	Yes	Yes
	5E. Net shape components (forgings, castings, extrusions, RTM, RFI elimination of machining and fastening) (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-13	5F. Additive manufacturing (for mass customization of cabin interior structures, depot repairs, etc.)	No	Yes	Yes	Yes	Yes	Yes
	5F. Additive manufacturing (for mass customization of cabin interior structures, depot repairs, etc.) (calculated)		1.0%	1.0%	1.0%	1.0%	2.0%
S-14	5G. 3-D Preforms (aeroelastically tailored, braided, woven, stitched)	No	No	No	No	No	Yes
	5G. 3-D Preforms (aeroelastically tailored, braided, woven, stitched) (calculated)						3.0%
S-15	6. Bonded joints, Innovations in structural joining	No	Yes	Yes	Yes	Yes	Yes
	6. Bonded joints, Innovations in structural joining (calculated)		1.0%	1.0%	1.0%	1.0%	3.0%
S-16	7. Damage tolerance concepts (3-D woven composites, PRSEUS, crack arrestment features, stitching, z pinning, etc.)	No	Yes	Yes	Yes	Yes	Yes
	7. Damage tolerance concepts (3-D woven composites, PRSEUS, crack arrestment features, stitching, z pinning, etc.) (calculated)		2.0%	2.0%	2.0%	2.0%	3.0%
S-17	8. Adaptive and morphing structures (wings, control surfaces, etc.)	No	No	No	No	No	Yes
	8. Adaptive and morphing structures (wings, control surfaces, etc.) (calculated)						3.0%
S-18	9. Advanced metallic joining (Friction Stir Welding, Advanced Welding)	Yes	Yes	Yes	Yes	Yes	Yes
	9. Advanced metallic joining (Friction Stir Welding, Advanced Welding) (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-19	10. High temperature materials for Insulation, thermal protection	No	Yes	Yes	Yes	Yes	Yes
	10. High temperature materials for Insulation, thermal protection (calculated)		1.0%	1.0%	1.0%	1.0%	1.0%
S-20	11. High temperature ceramics and coatings for engine components	No	No	Yes	No	Yes	Yes
	11. High temperature ceramics and coatings for engine components (calculated)			1.0%		1.0%	1.0%
S-21	12. Innovative load suppression, and vibration and aeromechanical stability control	No	No	No	No	No	Yes
	12. Innovative load suppression, and vibration and aeromechanical stability control (calculated)						1.0%
S-22	13. Multifunctional materials and structures (noise cancellation, embedded sensors, signal processing, actuators, antenna, lightning strike, etc.)	No	No	No	No	No	Yes

Technology Acronym / Title	Technology Subsystem Description	STA 2024 TP-A Evol.	STA 2024 TP-B Mod	STA 2024 TP-C Aggr	STA 2034 TP-B' Evol	STA 2034 TP-C' Mode	STA 2034 TP-D Aggr
	13. Multifunctional materials and structures (noise cancellation, embedded sensors, signal processing, actuators, antenna, lightning strike, etc.) (calculated)						1.0%
	Total Structural Weight Improvement	17.0%	28.0%	32.0%	28.0%	32.0%	49.0%

TABLE E-9 – STA SYSTEM AND CONFIGURATION TECHNOLOGIES

Technology Acronym / Title	Technology Subsystem Description	STA 2024 TP-A Evol.	STA 2024 TP-B Mod	STA 2024 TP-C Aggr	STA 2034 TP-B' Evol	STA 2034 TP-C' Mode	STA 2034 TP-D Aggr
Aircraft Systems							
Sys-1	More electric aircraft	Yes	Yes	Yes	Yes	Yes	Yes
	More electric aircraft (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Sys-2	Electric landing-gear drive	No	Yes	Yes	Yes	Yes	Yes
	Electric landing-gear drive (calculated)		0.5%	0.5%	0.5%	0.5%	0.5%
	Total Aircraft Systems Improvement	1.0%	1.5%	1.5%	1.5%	1.5%	1.5%

TABLE E-10 – STA ENGINE CONFIGURATIONS

Technology Acronym / Title	Technology Subsystem Description	STA 2024 TP-A Evol.	STA 2024 TP-B Mod	STA 2024 TP-C Aggr	STA 2034 TP-B' Evol	STA 2034 TP-C' Mode	STA 2034 TP-D Aggr
Engine Configuration		STA2024NE	STA 2024 Stretch	STA2034NE	STA 2024 Stretch	STA2034NE	STA2034NE
TSFC Performance Calculation	TSFC Improvement	6.0%	10.0%	13.9%	10.0%	13.9%	15.9%

Regional Jet Evaluations

TABLE E-11 – RJ AERODYNAMIC VISCOUS TECHNOLOGIES

Tech. Acronym / Title		Technology Subsystem Description	RJ 2024 TP-A Evol.	RJ 2024 TP-B Mod	RJ 2024 TP-C Aggr	RJ 2034 TP-B' Evol	RJ 2034 TP-C' Mode	RJ 2034 TP-D Aggr
Aerodynamic Efficiency (Viscous)								
AV-1	74	Natural laminar flow on nacelles	Yes	Yes	Yes	Yes	Yes	Yes
		Natural laminar flow on nacelles (calculated)	1.0%	1.3%	1.5%	1.3%	1.5%	1.5%
AV-2	75	Hybrid laminar flow on empennage	No	No	No	No	No	No
		Hybrid laminar flow on empennage (calculated)						
AV-3	76	Natural laminar flow on wings	No	No	Yes	No	Yes	Yes
		Natural laminar flow on wings (calculated)			5.0%		5.0%	8.0%
AV-4	79	Hybrid laminar flow on wing	No	No	No	No	No	No
		Hybrid laminar flow on wing (calculated)						
AV-5	80	Laminar flow coating/riblets	No	No	Yes	No	Yes	Yes
		Laminar flow coating/riblets (calculated)			2.0%		2.0%	2.0%
AV-6	81	Low friction paint coating	Yes	Yes	No	Yes	No	No
		Low friction paint coating (calculated)	2.0%	2.0%		2.0%		
		Total Aerodynamic Efficiency (Viscous) Improvement	3.0%	3.3%	8.5%	3.3%	8.5%	11.5%

TABLE E-12 – RJ AERODYNAMIC NON-VISCOUS TECHNOLOGIES

Tech. Acronym / Title		Technology Subsystem Description	RJ 2024 TP-A Evol.	RJ 2024 TP-B Mod	RJ 2024 TP-C Aggr	RJ 2034 TP-B' Evol	RJ 2034 TP-C' Mode	RJ 2034 TP-D Aggr
Aerodynamic Efficiency (Non-Viscous)								
ANV-1	85	Improved aero/transonic design	Yes	Yes	Yes	Yes	Yes	Yes
		Improved aero/transonic design (calculated)	2.0%	2.0%	3.0%	2.0%	3.0%	4.0%
ANV-2	86	Wingtip technologies (for fixed span)	Yes	Yes	Yes	Yes	Yes	Yes
		Wingtip technologies (for fixed span) (calculated)	1.0%	2.0%	2.0%	2.0%	2.0%	3.0%
ANV-3	87	Variable camber with existing control surfaces	No	No	No	No	No	No
		Variable camber with existing control surfaces (calculated)						
ANV-4	88	Adaptive compliant trailing edge	No	Yes	Yes	Yes	Yes	Yes
		Adaptive compliant trailing edge (calculated)		1.5%	2.0%	1.5%	2.0%	2.0%
ANV-5	90	Active stability control (reduced static margin)	No	No	No	No	No	No
		Active stability control (reduced static margin) (calculated)						
ANV-6	91	Reduction of loads (active smart wings)	No	No	No	No	No	No
		Reduction of loads (active smart wings) (calculated)						
ANV-7	93	Increased wing span:	Yes	Yes	Yes	Yes	Yes	Yes
		Increased wing span: (calculated)	1.5%	1.5%	1.5%	1.5%	1.5%	1.5%
		Total Aerodynamic Efficiency (Non-Viscous) Improvement	4.5%	7.0%	8.5%	7.0%	8.5%	10.5%

TABLE E-13 – RJ STRUCTURAL TECHNOLOGIES

Tech. Acronym / Title		Technology Subsystem Description	RJ 2024 TP-A Evol.	RJ 2024 TP-B Mod	RJ 2024 TP-C Aggr	RJ 2034 TP-B' Evol	RJ 2034 TP-C' Mode	RJ 2034 TP-D Aggr
S-2	120	1A. All composite fuselage	Yes	Yes	Yes	Yes	Yes	Yes
		1A. All composite fuselage (calculated)	4.8%	4.8%	4.8%	4.8%	4.8%	4.8%
S-2	121	1B. All composite wing	Yes	Yes	Yes	Yes	Yes	Yes
		1B. All composite wing (calculated)	2.9%	2.9%	2.9%	2.9%	2.9%	2.9%
S-3	122	1C. All composite nacelle	Yes	Yes	Yes	Yes	Yes	Yes
		1C. All composite nacelle (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-4	123	1D. All composite empennage	Yes	Yes	Yes	Yes	Yes	Yes
		1D. All composite empennage (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-5	124	2. Integrated structural health monitoring	No	No	No	No	No	No
		2. Integrated structural health monitoring (calculated)						
S-6	125	3. Advanced composite materials (higher strength, stiffness, toughness, damage tolerance, temperature)	No	Yes	Yes	Yes	Yes	Yes
		3. Advanced composite materials (higher strength, stiffness, toughness, damage tolerance, temperature) (calculated)		1.9%	2.9%	1.9%	2.9%	3.8%
S-7	126	4. Advanced airframe metal alloy (2000, 7000 series Al alloy, 3rd gen Al-temp Ti, etc.)	Yes	Yes	Yes	Yes	Yes	Yes
		4. Advanced airframe metal alloy (2000, 7000 series Al alloy, 3rd gen Al-temp Ti, etc.) (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-8	128	5A. Unitized construction (one piece fuselage barrel, wing box, skins, etc.)	Yes	Yes	Yes	Yes	Yes	Yes

Tech. Acronym		Technology Subsystem Description	RJ 2024			RJ 2034		
			TP-A	TP-B	TP-C	TP-B'	TP-C'	TP-D
Title			Evol.	Mod	Aggr	Evol	Mode	Aggr
		5A. Unitized construction (one piece fuselage barrel, wing box, skins, etc.) (calculated)	2.9%	2.9%	3.8%	2.9%	3.8%	4.8%
S-9	129	5B. Out of autoclave curing composites	No	Yes	Yes	Yes	Yes	Yes
		5B. Out of autoclave curing composites (calculated)		1.0%	1.0%	1.0%	1.0%	2.9%
S-10	130	5C. Automated tape laying, automated fiber placement	Yes	Yes	Yes	Yes	Yes	Yes
		5C. Automated tape laying, automated fiber placement (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-11	131	5D. Composite sandwich construction	No	Yes	Yes	Yes	Yes	Yes
		5D. Composite sandwich construction (calculated)		1.9%	1.9%	1.9%	1.9%	1.9%
S-12	132	5E. Net shape components (forgings, castings, extrusions, RTM, RFI elimination of machining and fastening)	Yes	Yes	Yes	Yes	Yes	Yes
		5E. Net shape components (forgings, castings, extrusions, RTM, RFI elimination of machining and fastening) (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-13	133	5F. Additive manufacturing (for mass customization of cabin interior structures, depot repairs, etc.)	No	Yes	Yes	Yes	Yes	Yes
		5F. Additive manufacturing (for mass customization of cabin interior structures, depot repairs, etc.) (calculated)		1.0%	1.0%	1.0%	1.0%	1.9%
S-14	134	5G. 3-D Preforms (aeroelastically tailored, braided, woven, stitched)	No	No	No	No	No	Yes
		5G. 3-D Preforms (aeroelastically tailored, braided, woven, stitched) (calculated)						2.9%
S-15	135	6. Bonded joints, Innovations in structural joining	No	Yes	Yes	Yes	Yes	Yes
		6. Bonded joints, Innovations in structural joining (calculated)		1.0%	1.0%	1.0%	1.0%	2.9%
S-16	136	7. Damage tolerance concepts (3-D woven composites, PRSEUS, crack arrestment features, stitching, z pinning, etc.)	No	Yes	Yes	Yes	Yes	Yes
		7. Damage tolerance concepts (3-D woven composites, PRSEUS, crack arrestment features, stitching, z pinning, etc.) (calculated)		1.9%	1.9%	1.9%	1.9%	2.9%
S-17	137	8. Adaptive and morphing structures (wings, control surfaces, etc.)	No	No	No	No	No	No
		8. Adaptive and morphing structures (wings, control surfaces, etc.) (calculated)						
S-18	138	9. Advanced metallic joining (Friction Stir Welding, Advanced Welding)	Yes	Yes	Yes	Yes	Yes	Yes
		9. Advanced metallic joining (Friction Stir Welding, Advanced Welding) (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
S-19	139	10. High temperature materials for Insulation, thermal protection	No	Yes	Yes	Yes	Yes	Yes
		10. High temperature materials for Insulation, thermal protection (calculated)		1.0%	1.0%	1.0%	1.0%	1.0%
S-20	140	11. High temperature ceramics and coatings for engine components	No	No	Yes	No	Yes	Yes
		11. High temperature ceramics and coatings for engine components (calculated)			1.0%		1.0%	1.0%
S-21	141	12. Innovative load suppression, and vibration and aeromechanical stability control	No	No	No	No	No	No

Tech. Acronym / Title		Technology Subsystem Description	RJ 2024 TP-A Evol.	RJ 2024 TP-B Mod	RJ 2024 TP-C Aggr	RJ 2034 TP-B' Evol	RJ 2034 TP-C' Mode	RJ 2034 TP-D Aggr
		12. Innovative load suppression, and vibration and aeromechanical stability control (calculated)						
S-22	142	13. Multifunctional materials and structures (noise cancellation, embedded sensors, signal processing, actuators, antenna, lightning strike, etc.)	No	No	No	No	No	Yes
		13. Multifunctional materials and structures (noise cancellation, embedded sensors, signal processing, actuators, antenna, lightning strike, etc.) (calculated)						1.0%
		Total Structural Weight Improvement	16.2%	25.7%	28.5%	25.7%	28.5%	39.9%

TABLE E-14 – RJ SYSTEM AND CONFIGURATION TECHNOLOGIES

Tech. Acronym / Title		Technology Subsystem Description	RJ 2024 TP-A Evol.	RJ 2024 TP-B Mod	RJ 2024 TP-C Aggr	RJ 2034 TP-B' Evol	RJ 2034 TP-C' Mode	RJ 2034 TP-D Aggr
Aircraft Systems								
Sys-1	144	More electric aircraft	Yes	Yes	Yes	Yes	Yes	Yes
		More electric aircraft (calculated)	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
Sys-2	145	Electric landing-gear drive	No	Yes	Yes	Yes	Yes	Yes
		Electric landing-gear drive (calculated)		0.5%	0.5%	0.5%	0.5%	0.5%
		Total Aircraft Systems Improvement	1.0%	1.5%	1.5%	1.5%	1.5%	1.5%

TABLE E-15 – RJ ENGINE CONFIGURATIONS

Technology Acronym / Title	Technology Subsystem Description	RJ 2024 TP-A Evol.	RJ 2024 TP-B Mod	RJ 2024 TP-C Aggr	RJ 2034 TP-B' Evol	RJ 2034 TP-C' Mode	RJ 2034 TP-D Aggr
Engine Configuration		RJ2024NE	RJ2024 Stretch	RJ2034NE	RJ2024 Stretch	RJ2034NE	RJ2034NE
TSFC Performance Calculation	TSFC Improvement	17.0%	19.0%	21.0%	19.0%	21.0%	26.8%

APPENDIX F—Maintenance Assessment of Technology Candidates

The following are identified impacts to maintenance aspects from each individual technology by the SMEs. The tables indicate by technology the level of impact it will have on the maintenance operations and a description of the assessment

TABLE F-1 – O&M IMPACTS FOR VISCOUS AND NON-VISCOUS TECHNOLOGIES

Code	Technology	Potential Impact	Description
AV-1	Natural laminar flow on nacelles	Significant	Leading edge and surfaces must be kept smooth and free of defect to maintain laminar flow and scheduled inspection and repaint/resurface may be needed
			Fuel savings may not be fully realized, as aircraft may be required to carry additional fuel to account for in-flight loss of laminar flow
AV-2	Hybrid laminar flow on empennage	Significant	Leading edge and surfaces must be kept smooth and free of defect to maintain laminar flow and scheduled inspection and repaint/resurface may be needed
		Significant	Suction holes need to be maintained to ensure they remain open
		Moderate	Vacuum device must be inspected and maintained
		Minor	Suction holes will require new approach when painting
			Fuel savings may not be fully realized, as aircraft may be required to carry additional fuel to account for in-flight loss of laminar flow
AV-3	Natural laminar flow on wings	Significant	Leading edge and surfaces must be kept smooth and free of defect to maintain laminar flow and scheduled inspection and repaint/resurface may be needed
			Fuel savings may not be fully realized, as aircraft may be required to carry additional fuel to account for in-flight loss of laminar flow
AV-4	Hybrid laminar flow on wing	Significant	Leading edge and surfaces must be kept smooth and free of defect to maintain laminar flow and scheduled inspection and repaint/resurface may be needed
		Significant	Suction holes need to be maintained to ensure they remain open
		Moderate	Vacuum device must be inspected and maintained
		Minor	Suction holes will require new approach when painting
			Fuel savings may not be fully realized, as aircraft may be required to carry additional fuel to account for in-flight loss of laminar flow
AV-5	Laminar flow coating/riblets	Minor/ Moderate	Coatings/riblets must remain free of defect to maintain laminar flow
		Minor/ Moderate	Riblets may erode and may require periodic removal and replacement
ANV-1	Improved aero/transonic design	None	
ANV-2	Wingtip technologies (for fixed span)	Minor/ Moderate	New component must be accounted for in maintenance cycles
ANV-3	Variable camber with existing control surfaces	Significant	Extra actuator and movable parts require inspection and maintenance
ANV-4	Adaptive compliant trailing edge	Moderate	Adds structural complexity and additional actuators to the trailing edge of the wing
ANV-5	Active stability control (reduced static margin)	Moderate	The extra sensor and feedback loop add system complexity, and maintenance also involves software upgrades and testing

Code	Technology	Potential Impact	Description
ANV-6	Reduction of loads (active smart wings)	Significant	New sensors to monitor wing loading must be included
		Moderate	New advanced actuators must be included
ANV-7	Increased wingspan	Minor	May increase the complexity/parts count for the wing

TABLE F-2 – MAINTENANCE IMPACTS FOR SYSTEMS TECHNOLOGIES

Code	Technology	Potential Impact	Description
S-0	All composite aircraft	Significant	May significantly alter the conduct of inspections
		Significant	May significantly alter the frequency with and how maintenance and repair is performed
S-1	All composite fuselage	Significant	May significantly alter the conduct of inspections
		Significant	May significantly alter the frequency with and how maintenance and repair is performed
S-2	All composite wing	Significant	May significantly alter the conduct of inspections
		Significant	May significantly alter the frequency with and how maintenance and repair is performed
S-3	All composite nacelle	Significant	May significantly alter the conduct of inspections
			May significantly alter the frequency with and how maintenance and repair is performed
S-4	All composite empennage	Significant	May significantly alter the conduct of inspections
			May significantly alter the frequency with and how maintenance and repair is performed
S-5	Integrated structural health monitoring	Moderate	Adds multiple sensors to structural elements that must be maintained
			May reduce some maintenance costs, particularly in the area of inspections
			Software upgrades and testing may increase maintenance
S-6	Advanced composite materials (higher strength, stiffness, toughness, damage tolerance, temperature)	None	
S-7	Advanced airframe metal alloy (2000, 7000 series A1 alloy, 3rd gen A1-Li, higher temp Ti, etc.	None	
S-8	Unitized construction (one piece fuselage barrel, wing box, skins, etc.)	Moderate	Larger one-piece components when damaged will require new repair processes or will require replacement of larger, more expensive components
			Though larger one-piece external components may limit access to internal components and hamper inspection of structural elements, it significantly reduces the number of parts and joints, which are to be inspected otherwise
S-9	Out of autoclave curing composites	None	
S-10	Automated tape laying, automated fiber placement	Moderate	Larger one-piece components when damaged will require new repair processes or will require replacement of larger, more expensive components
			Though larger one-piece external components may limit access to internal components and hamper inspection of structural elements, it significantly reduces the number of parts and joints, which are to be inspected otherwise
S-11	Composite sandwich construction	None	

Code	Technology	Potential Impact	Description
S-12	Net shape components (forgings, castings, extrusions, RTM, RFI, elimination of machining and fastening)		Though larger one-piece external components may limit access to internal components and hamper inspection of structural elements, it significantly reduces the number of parts and joints, which are to be inspected otherwise
S-13	Additive manufacturing (for mass customization of cabin interior structures, depot repairs, etc.)		Though larger one-piece external components may limit access to internal components and hamper inspection of structural elements, it significantly reduces the number of parts and joints, which are to be inspected otherwise
S-14	3-D Preforms (aero elastically tailored, braided, woven, stitched)	None	
S-15	Bonded joints, innovations in structural joining	Moderate	Adhesives may debond and require repair, which is different from conventional joint repair
S-16	Damage tolerance concepts (3-D woven composites, PRSEUS, crack arrestment features, stitching, z pinning, etc.)	None	
S-17	Adaptive and morphing structures (wings, control surfaces, etc.)	Significant	Added complexity wings and control surfaces to support shape changes
		Significant	New sensors to monitor loading must be including
S-18	Advanced metallic joining (Friction Stir Welding, Advanced Welding)		Better joining technology yields better joints, which require less maintenance
S-19	High temperature materials for Insulation, thermal protection	None	
S-20	High temperature ceramics and coatings for engine components	Minor	New material and coatings need to be inspected
S-21	Innovative load suppression, and vibration and aeromechanical stability control	Significant	New sensors to monitor loading and vibrations must be included
S-22	Multifunctional materials and structures (noise cancellation, embedded sensors, signal processing, actuators, antenna, lightning strike, etc.)	Significant	New sensors, actuators, etc., must be included

TABLE F-3 – MAINTENANCE IMPACTS FOR ENGINE TECHNOLOGIES

Code	Technology	Potential Impact	Description
E-1	Advanced turbofans (non-geared)	None	
E-2	Geared turbofans	Moderate	Added complexity and parts count due to the addition of a gear
E-3	Open rotor – CROR	None	

APPENDIX G—Piano 5 User Factor Parameters

Piano includes user factors that an analyst can input that will enable the Piano model to resize an aircraft. Subsequently, the revised aircraft weight and engine parameters can be used to estimate fuel burn reductions and as an input into cost estimating models. The following figure shows the available user factors, their name, their definition, and min/max/default values. The User Factors marked in ORANGE TEXT are the factors used for modeling technology improvements in the study and were the core of evaluation by the Technical SMEs and review by the TAG.

TABLE G-1 – USER FACTOR

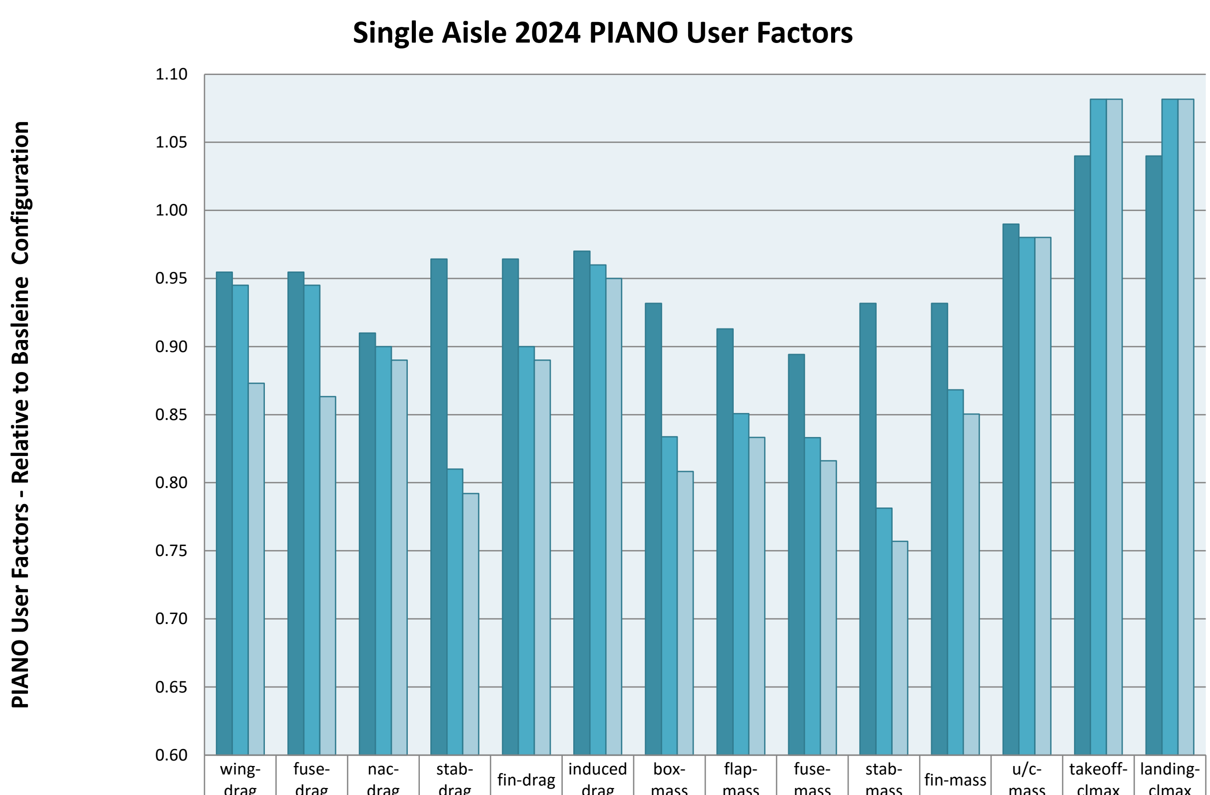
USER FACTOR NAME	DEFINITION	MIN Value	MAX Value	DEFAULT Value
USER-ADJUST-CL-CD-CURVE	User-adjustment of CL-dependent drag. It is a list of numbers representing alternately a CL and a corresponding Cd increment or decrement. (referenced to trapezoidal wing-area)	-1.0	1.0	0
USER-ADJUST-MACH-CD-CURVE	User-adjustment of Mach-dependent drag. It is a list of numbers representing alternately a Mach number and a corresponding Cd increment (+ or -) (referenced to trapezoidal wing-area).	-1.0	1.0	0
USER-CDS-INCREMENT	Drag area increment {Cd * S} for any unaccounted items. Units are sq. meters or sq. feet	-10 sq.m	10 sq.m	0 sq.m
USER-FACTOR-ON-APPROACH-FUEL	Factor applied to approach fuel	0	5.0	1
USER-FACTOR-ON-ASYMMETRIC-DRAG	Factor applied to asymmetric drag due to yaw with one engine out. See also user-factor-on-windmill-drag.	0.0	2.0	1
USER-FACTOR-ON-BOX-MASS	This factor is applied to the wing structural mass only. A separate factor exists for the flaps.	0.1	2	1
USER-FACTOR-ON-CLIMB-RATING	Applied to engine thrust characteristics	0.5	1.5	1
USER-FACTOR-ON-CONTINUOUS-RATING	Applied to engine thrust characteristics	0.5	1.5	1
USER-FACTOR-ON-CRUISE-RATING	Applied to engine thrust characteristics	0.5	1.5	1
USER-FACTOR-ON-DIVERGENCE-MACH	Divergence Mach is calculated internally as a function of t/c, sweepback, CL, and the parameter roof-top-end. This factor is then applied to the result. The divergence Mach at a given CL can be examined through the drag report.	0.9	1.1	1
USER-FACTOR-ON-DIVERSION-FUEL	Factor applied to diversion fuel calculation.	0.1	2	1
USER-FACTOR-ON-FIN-DRAG	Factor applied to the fin zero-lift drag	0	5	1
USER-FACTOR-ON-FIN-MASS	Factor on estimated vertical tail mass.	0	10	1
USER-FACTOR-ON-FLAP-MASS	Factor on estimated wing flap mass	0.1	5	1
USER-FACTOR-ON-FUSE-DRAG	Factor applied to fuselage zero-lift drag	0	5	1

USER FACTOR NAME	DEFINITION	MIN Value	MAX Value	DEFAULT Value
USER-FACTOR-ON-FUSE-MASS	Factor on estimated fuselage mass.	0.1	2	1
USER-FACTOR-ON-HOLD-FUEL	Factor applied to holding fuel calculation	0.1	2.0	1
USER-FACTOR-ON-INDUCED-DRAG	Factor applied to the wing induced drag	0.5	1.5	1
USER-FACTOR-ON-LANDING-CLMAX	This factor is applied to the total CLmax of the aircraft at landing flap deflections.	0.5	2	1
USER-FACTOR-ON-LANDING-L/D	This factor is applied to the calculated overall Lift/Drag ratio in the landing configuration (shown in field reports). Used to change the final approach and landing drags.	0.5	1.5	1
USER-FACTOR-ON-NAC-DRAG	Factor applied to nacelle zero-lift drag	0	5	1
USER-FACTOR-ON-SFC	This factor is applied to all fuel consumption characteristics (sfc loops and idle flow).	0.1	2	1
USER-FACTOR-ON-STAB-DRAG	Factor applied to stabilizer zero-lift drag	0	5	1
USER-FACTOR-ON-STAB-MASS	Factor on estimated horizontal tail mass	0	10	1
USER-FACTOR-ON-TAKEOFF-CLMAX	This factor is applied to the total CLmax of the aircraft at takeoff flap deflections.	0.5	2	1
USER-FACTOR-ON-TAKEOFF-FUEL	Factor applied to takeoff fuel	0	5.0	1
USER-FACTOR-ON-TAKEOFF-L/D	This factor is applied to the calculated overall Lift/Drag ratio in the takeoff configuration (shown in field reports). Used to change the takeoff drag.	0.5	1.5	1
USER-FACTOR-ON-TAKEOFF-RATING	This factor should only be used to simulate an engine de-rating or throttle-push when calculating takeoff performance. The given value of reference-thrust-per-engine will still be used to find the engine mass, and all other ratings will still be defined relative to the reference thrust.	0.5	1.5	1
USER-FACTOR-ON-TAXI-IN-FUEL	Factor applied to taxi-in fuel	0	5.0	1
USER-FACTOR-ON-TAXI-OUT-FUEL	Factor applied to taxi-out fuel	0	5.0	1
USER-FACTOR-ON-TOTAL-DRAG	A factor applied to the total drag. This should only be used for management-style studies and has limited physical significance.	0.5	1.5	1
USER-FACTOR-ON-U/C-MASS	Factor on undercarriage mass	0	2	1
USER-FACTOR-ON-WINDMILL-DRAG	Factor applied to windmilling drag due to a failed engine.	0.0	2.0	1
USER-FACTOR-ON-WING-DRAG	Factor applied to wing zero-lift drag	0	5	1

Source: www.piano.aero

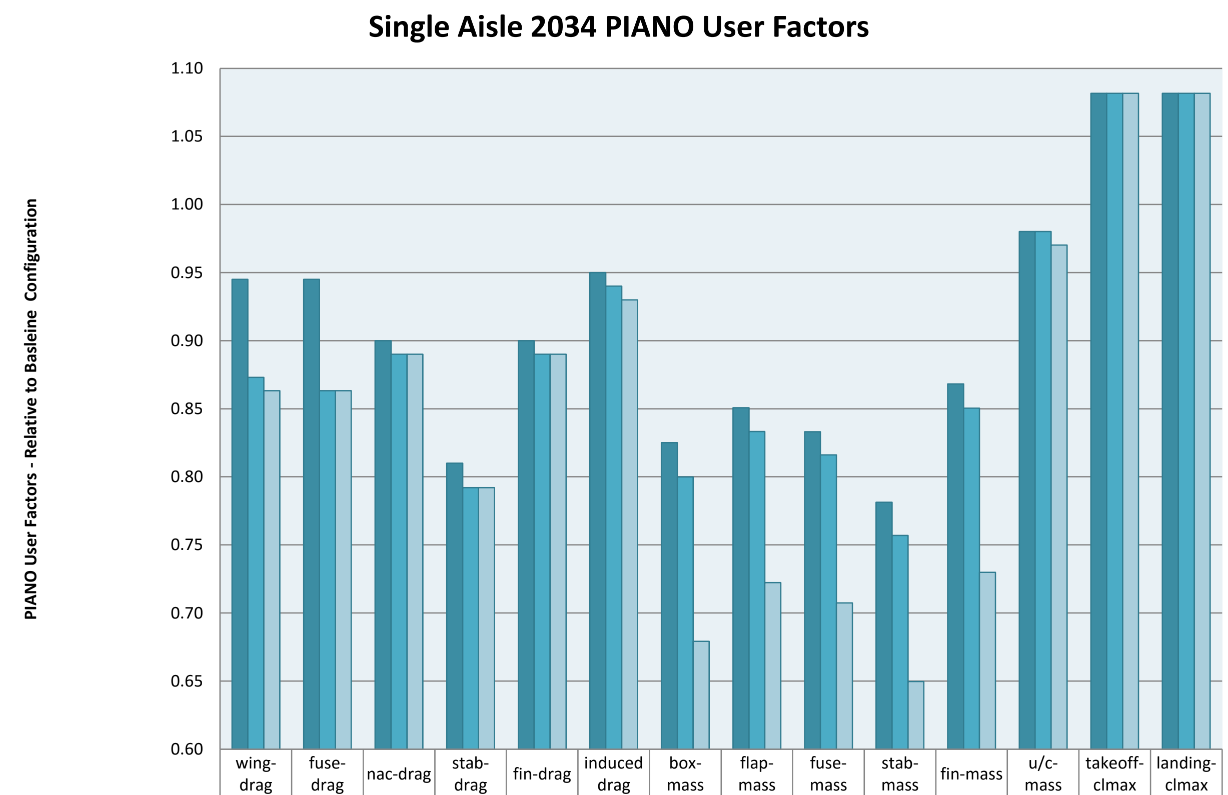
APPENDIX H— Piano 5 User Factors By Configuration

The following are the resulting composite Piano User Factors used in the study to derive optimized resized aircraft. The graphs show a comparison across EIS years for each aircraft class. The data shown in the graphs are only the variables provided by the SME for use in optimized aircraft resizing in Piano.



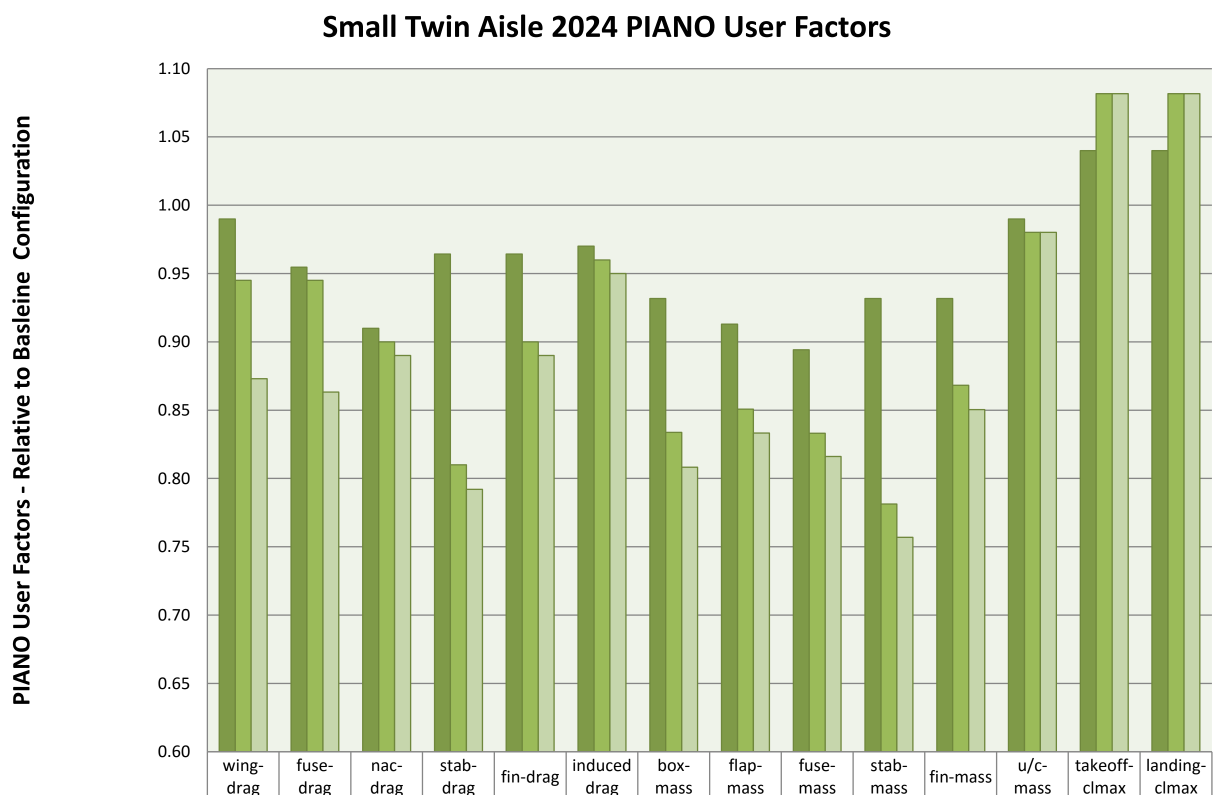
	wing-drag	fuse-drag	nac-drag	stab-drag	fin-drag	induced drag	box-mass	flap-mass	fuse-mass	stab-mass	fin-mass	u/c-mass	takeoff-clmax	landing-clmax
SA Evolutionary - 2024	0.95	0.95	0.91	0.96	0.96	0.97	0.93	0.91	0.89	0.93	0.93	0.99	1.04	1.04
SA Moderate - 2024	0.95	0.95	0.90	0.81	0.90	0.96	0.83	0.85	0.83	0.78	0.87	0.98	1.08	1.08
SA Aggressive - 2024	0.87	0.86	0.89	0.79	0.89	0.95	0.81	0.83	0.82	0.76	0.85	0.98	1.08	1.08

FIGURE H-1 –SA 2024 PIANO 5 USER FACTORS



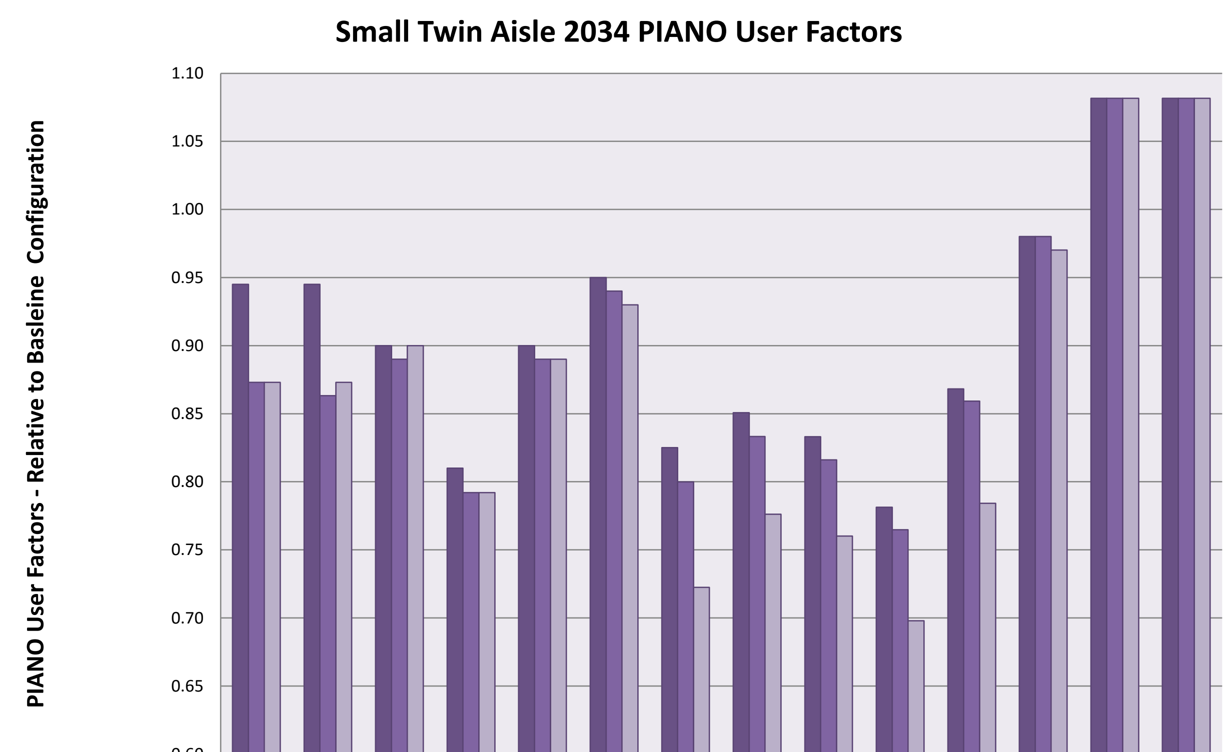
	wing-drag	fuse-drag	nac-drag	stab-drag	fin-drag	induced drag	box-mass	flap-mass	fuse-mass	stab-mass	fin-mass	u/c-mass	takeoff-clmax	landing-clmax
SA Evolutionary - 2034	0.95	0.95	0.90	0.81	0.90	0.95	0.83	0.85	0.83	0.78	0.87	0.98	1.08	1.08
SA Moderate - 2034	0.87	0.86	0.89	0.79	0.89	0.94	0.80	0.83	0.82	0.76	0.85	0.98	1.08	1.08
SA Aggressive - 2034	0.86	0.86	0.89	0.79	0.89	0.93	0.68	0.72	0.71	0.65	0.73	0.97	1.08	1.08

FIGURE H-2 –SA 2034 PIANO 5 USER FACTORS



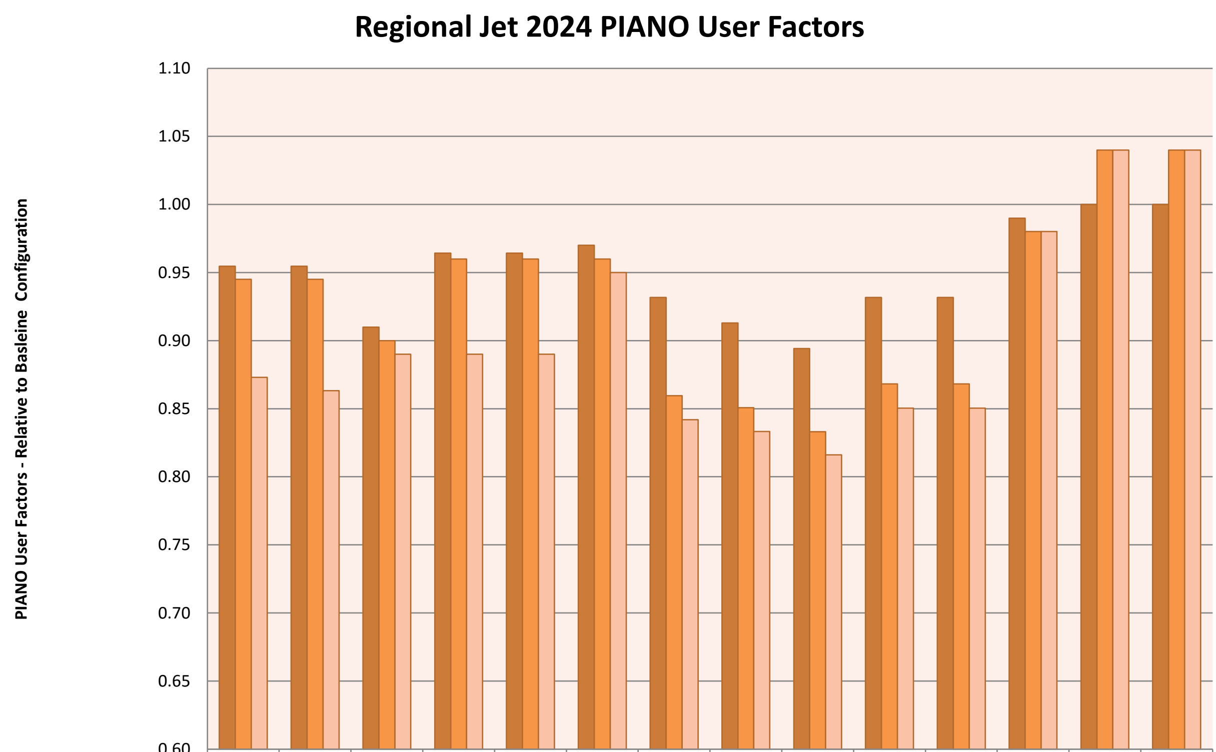
	wing-drag	fuse-drag	nac-drag	stab-drag	fin-drag	induced drag	box-mass	flap-mass	fuse-mass	stab-mass	fin-mass	u/c-mass	takeoff-clmax	landing-clmax
TA Evolutionary - 2024	0.99	0.95	0.91	0.96	0.96	0.97	0.93	0.91	0.89	0.93	0.93	0.99	1.04	1.04
TA Moderate - 2024	0.95	0.95	0.90	0.81	0.90	0.96	0.83	0.85	0.83	0.78	0.87	0.98	1.08	1.08
TA Aggressive - 2024	0.87	0.86	0.89	0.79	0.89	0.95	0.81	0.83	0.82	0.76	0.85	0.98	1.08	1.08

FIGURE H-3 –STA 2024 PIANO 5 USER FACTORS



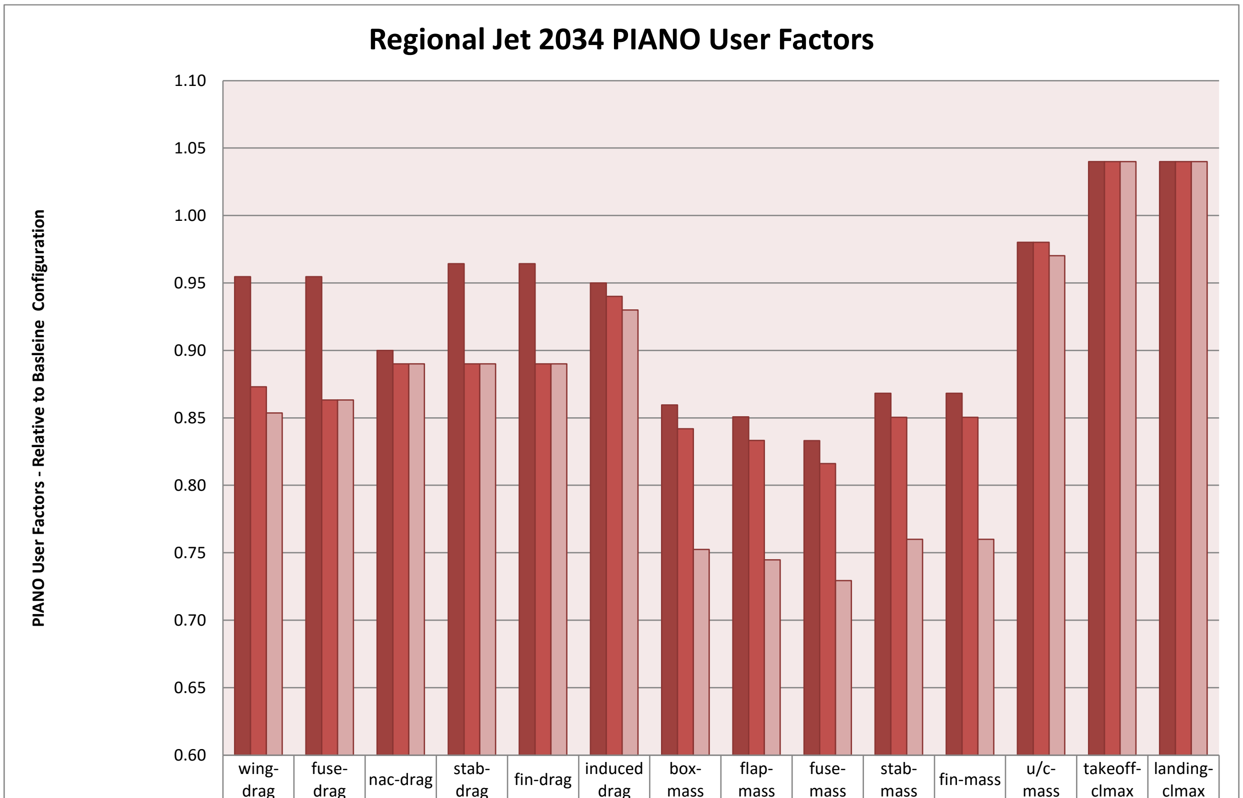
	wing-drag	fuse-drag	nac-drag	stab-drag	fin-drag	induced drag	box-mass	flap-mass	fuse-mass	stab-mass	fin-mass	u/c-mass	takeoff-clmax	landing-clmax
TA Evolutionary - 2034	0.95	0.95	0.90	0.81	0.90	0.95	0.83	0.85	0.83	0.78	0.87	0.98	1.08	1.08
TA Moderate - 2034	0.87	0.86	0.89	0.79	0.89	0.94	0.80	0.83	0.82	0.76	0.86	0.98	1.08	1.08
TA Aggressive - 2034	0.87	0.87	0.90	0.79	0.89	0.93	0.72	0.78	0.76	0.70	0.78	0.97	1.08	1.08

FIGURE H-4 –STA 2034 PIANO 5 USER FACTORS



	wing-drag	fuse-drag	nac-drag	stab-drag	fin-drag	induced drag	box-mass	flap-mass	fuse-mass	stab-mass	fin-mass	u/c-mass	takeoff-clmax	landing-clmax
RJ Evolutionary - 2024	0.95	0.95	0.91	0.96	0.96	0.97	0.93	0.91	0.89	0.93	0.93	0.99	1.00	1.00
RJ Moderate - 2024	0.95	0.95	0.90	0.96	0.96	0.96	0.86	0.85	0.83	0.87	0.87	0.98	1.04	1.04
RJ Aggressive - 2024	0.87	0.86	0.89	0.89	0.89	0.95	0.84	0.83	0.82	0.85	0.85	0.98	1.04	1.04

FIGURE H-5 –RJ 2024 PIANO 5 USER FACTORS



	wing-drag	fuse-drag	nac-drag	stab-drag	fin-drag	induced drag	box-mass	flap-mass	fuse-mass	stab-mass	fin-mass	u/c-mass	takeoff-clmax	landing-clmax
RJ Evolutionary - 2034	0.95	0.95	0.90	0.96	0.96	0.95	0.86	0.85	0.83	0.87	0.87	0.98	1.04	1.04
RJ Moderate - 2034	0.87	0.86	0.89	0.89	0.89	0.94	0.84	0.83	0.82	0.85	0.85	0.98	1.04	1.04
RJ Aggressive - 2034	0.85	0.86	0.89	0.89	0.89	0.93	0.75	0.74	0.73	0.76	0.76	0.97	1.04	1.04

FIGURE H-6 –RJ 2034 PIANO 5 USER FACTORS

APPENDIX I—Design Heritage Factors

In this study Design Heritage Factors was used to adjust the calculated development cost results to account for the amount of new development required. Design Heritage Factors are a value between "0" and "1", where: 0 means 0% new design and 1 means 100% new design. The tables in this appendix show the overall composite effect on each subsystem based on the underlying technologies employed for each of the deployment scenario (E = evolutionary, M = moderate, A = aggressive). These factors were determined by the SMEs. As the model is probabilistic based, these parameters represent the triangular distribution (low, most likely, high values).

TABLE I-1 – SA DESIGN HERITAGE FACTORS

	Low						Most Likely						High					
	2024			2034			2024			2034			2024			2034		
	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A
Air Vehicle																		
Airframe Integ.																		
Airframe																		
Fuselage	0.49	0.64	0.63	0.70	0.70	0.70	0.55	0.72	0.73	0.76	0.78	1.00	0.65	0.92	1.00	0.86	0.98	1.00
Wing																		
Structure Box	0.61	0.71	0.75	0.77	0.78	0.86	0.67	0.79	0.85	0.83	0.86	1.00	0.77	0.99	1.00	0.93	1.00	1.00
Flaps	0.62	0.74	0.74	0.82	0.81	0.84	0.68	0.82	0.84	0.88	0.89	1.00	0.78	1.00	1.00	0.98	1.00	1.00
Slats	0.40	0.57	0.56	0.65	0.64	0.65	0.46	0.65	0.66	0.71	0.72	1.00	0.56	0.85	0.96	0.81	0.92	1.00
Spoilers	0.40	0.54	0.56	0.65	0.64	0.65	0.46	0.62	0.66	0.71	0.72	1.00	0.56	0.82	0.96	0.81	0.92	1.00
Ailerons	0.62	0.69	0.69	0.78	0.77	0.81	0.68	0.77	0.79	0.84	0.85	1.00	0.78	0.97	1.00	0.94	1.00	1.00
Winglets	0.04	0.57	0.56	0.62	0.62	0.63	0.10	0.65	0.66	0.68	0.70	1.00	0.20	0.85	0.96	0.78	0.90	1.00
Empennage																		
Stabilizer	0.49	0.71	0.72	0.78	0.77	0.77	0.55	0.79	0.82	0.84	0.85	1.00	0.65	0.99	1.00	0.94	1.00	1.00
Fin	0.49	0.71	0.72	0.78	0.77	0.77	0.55	0.79	0.82	0.84	0.85	1.00	0.65	0.99	1.00	0.94	1.00	1.00
Landing Gear	0.04	0.33	0.31	0.42	0.40	0.42	0.10	0.41	0.41	0.48	0.48	1.00	0.20	0.61	0.71	0.58	0.68	1.00
Propulsion																		
Engine																		
Core	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pylon	0.14	0.22	0.20	0.31	0.29	0.27	0.20	0.30	0.30	0.37	0.37	1.00	0.30	0.50	0.60	0.47	0.57	1.00
Nacelle	0.56	0.62	0.65	0.72	0.71	0.71	0.62	0.70	0.75	0.78	0.79	1.00	0.72	0.90	1.00	0.88	0.99	1.00
Fuel System	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00
Systems																		
Aux Power Unit	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00
Surface Controls	0.63	0.73	0.72	0.81	0.80	0.80	0.69	0.81	0.82	0.87	0.88	1.00	0.79	1.00	1.00	0.97	1.00	1.00
Hydraulics	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00
Electrical	0.34	0.32	0.30	0.42	0.40	0.38	0.40	0.40	0.40	0.48	0.48	1.00	0.50	0.60	0.70	0.58	0.68	1.00
Furnishings	0.04	0.20	0.18	0.24	0.22	0.22	0.10	0.28	0.28	0.30	0.30	1.00	0.20	0.48	0.58	0.40	0.50	1.00
Air Conditioning	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00
Avionics	0.34	0.32	0.30	0.42	0.40	0.38	0.40	0.40	0.40	0.48	0.48	1.00	0.50	0.60	0.70	0.58	0.68	1.00
Misc Systems	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00

TABLE I-2 – STA DESIGN HERITAGE FACTORS

	Low						Most Likely						High					
	2024			2034			2024			2034			2024			2034		
	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A
Air Vehicle																		
Airframe Integ.																		
Airframe																		
Fuselage	0.49	0.62	0.63	0.70	0.70	0.70	0.55	0.70	0.73	0.76	0.78	1.00	0.65	0.90	1.00	0.86	0.98	1.00
Wing																		
Structure Box	0.51	0.67	0.76	0.75	0.79	0.86	0.57	0.75	0.86	0.81	0.87	1.00	0.67	0.95	1.00	0.91	1.00	1.00
Flaps	0.62	0.72	0.75	0.82	0.82	0.84	0.68	0.80	0.85	0.88	0.90	1.00	0.78	1.00	1.00	0.98	1.00	1.00
Slats	0.40	0.54	0.57	0.65	0.66	0.67	0.46	0.62	0.67	0.71	0.74	1.00	0.56	0.82	0.97	0.81	0.94	1.00
Spoilers	0.40	0.51	0.57	0.65	0.66	0.67	0.46	0.59	0.67	0.71	0.74	1.00	0.56	0.79	0.97	0.81	0.94	1.00
Ailerons	0.62	0.67	0.70	0.78	0.78	0.82	0.68	0.75	0.80	0.84	0.86	1.00	0.78	0.95	1.00	0.94	1.00	1.00
Winglets	0.11	0.57	0.56	0.62	0.62	0.63	0.17	0.65	0.66	0.68	0.70	1.00	0.27	0.85	0.96	0.78	0.90	1.00
Empennage																		
Stabilizer	0.49	0.70	0.73	0.78	0.78	0.77	0.55	0.78	0.83	0.84	0.86	1.00	0.65	0.98	1.00	0.94	1.00	1.00
Fin	0.49	0.70	0.73	0.78	0.78	0.77	0.55	0.78	0.83	0.84	0.86	1.00	0.65	0.98	1.00	0.94	1.00	1.00
Landing Gear	0.04	0.33	0.34	0.42	0.42	0.44	0.10	0.41	0.44	0.48	0.50	1.00	0.20	0.61	0.74	0.58	0.70	1.00
Propulsion																		
Engine																		
Core	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pylon	0.14	0.22	0.20	0.31	0.29	0.27	0.20	0.30	0.30	0.37	0.37	1.00	0.30	0.50	0.60	0.47	0.57	1.00
Nacelle	0.56	0.62	0.65	0.72	0.71	0.71	0.62	0.70	0.75	0.78	0.79	1.00	0.72	0.90	1.00	0.88	0.99	1.00
Fuel System	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00
Systems																		
Aux Power Unit	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00
Surface Controls	0.58	0.73	0.72	0.81	0.80	0.80	0.64	0.81	0.82	0.87	0.88	1.00	0.74	1.00	1.00	0.97	1.00	1.00
Hydraulics	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00
Electrical	0.34	0.32	0.30	0.42	0.40	0.38	0.40	0.40	0.40	0.48	0.48	1.00	0.50	0.60	0.70	0.58	0.68	1.00
Furnishings	0.00	0.20	0.18	0.24	0.22	0.22	0.00	0.28	0.28	0.30	0.30	1.00	0.00	0.48	0.58	0.40	0.50	1.00
Air Conditioning	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00
Avionics	0.34	0.32	0.30	0.42	0.40	0.38	0.40	0.40	0.40	0.48	0.48	1.00	0.50	0.60	0.70	0.58	0.68	1.00
Misc Systems	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00

TABLE I-3 – RJ DESIGN HERITAGE FACTORS

	Low						Most Likely						High					
	2024			2034			2024			2034			2024			2034		
	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A
Air Vehicle																		
Airframe Integ.																		
Airframe																		
Fuselage	0.49	0.62	0.62	0.68	0.68	0.65	0.55	0.70	0.72	0.74	0.76	1.00	0.65	0.90	1.00	0.84	0.96	1.00
Wing																		
Structure Box	0.56	0.67	0.72	0.72	0.78	0.79	0.62	0.75	0.82	0.78	0.86	1.00	0.72	0.95	1.00	0.88	1.00	1.00
Flaps	0.40	0.62	0.63	0.70	0.70	0.68	0.46	0.70	0.73	0.76	0.78	1.00	0.56	0.90	1.00	0.86	0.98	1.00
Slats	0.40	0.57	0.56	0.62	0.62	0.59	0.46	0.65	0.66	0.68	0.70	1.00	0.56	0.85	0.96	0.78	0.90	1.00
Spoilers	0.40	0.54	0.56	0.62	0.62	0.59	0.46	0.62	0.66	0.68	0.70	1.00	0.56	0.82	0.96	0.78	0.90	1.00
Ailerons	0.40	0.54	0.56	0.62	0.62	0.59	0.46	0.62	0.66	0.68	0.70	1.00	0.56	0.82	0.96	0.78	0.90	1.00
Winglets	0.04	0.57	0.56	0.62	0.62	0.59	0.10	0.65	0.66	0.68	0.70	1.00	0.20	0.85	0.96	0.78	0.90	1.00
Empennage																		
Stabilizer	0.49	0.62	0.62	0.68	0.68	0.65	0.55	0.70	0.72	0.74	0.76	1.00	0.65	0.90	1.00	0.84	0.96	1.00
Fin	0.49	0.62	0.62	0.68	0.68	0.65	0.55	0.70	0.72	0.74	0.76	1.00	0.65	0.90	1.00	0.84	0.96	1.00
Landing Gear	0.04	0.30	0.28	0.37	0.40	0.38	0.10	0.38	0.38	0.43	0.48	1.00	0.20	0.58	0.68	0.53	0.68	1.00

	Low						Most Likely						High					
	2024			2034			2024			2034			2024			2034		
	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A
Propulsion																		
Engine																		
Core	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Pylon	0.14	0.18	0.16	0.25	0.23	0.21	0.20	0.26	0.26	0.31	0.31	1.00	0.30	0.46	0.56	0.41	0.51	1.00
Nacelle	0.56	0.62	0.65	0.72	0.71	0.68	0.62	0.70	0.75	0.78	0.79	1.00	0.72	0.90	1.00	0.88	0.99	1.00
Fuel System	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00
Systems																		
Aux Power Unit	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00
Surface Controls	0.34	0.44	0.43	0.55	0.54	0.52	0.40	0.52	0.53	0.61	0.62	1.00	0.50	0.72	0.83	0.71	0.82	1.00
Hydraulics	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00
Electrical	0.34	0.32	0.30	0.42	0.40	0.38	0.40	0.40	0.40	0.48	0.48	1.00	0.50	0.60	0.70	0.58	0.68	1.00
Furnishings	0.04	0.20	0.18	0.24	0.22	0.20	0.10	0.28	0.28	0.30	0.30	1.00	0.20	0.48	0.58	0.40	0.50	1.00
Air Conditioning	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00
Avionics	0.34	0.32	0.30	0.42	0.40	0.38	0.40	0.40	0.40	0.48	0.48	1.00	0.50	0.60	0.70	0.58	0.68	1.00
Misc Systems	0.18	0.18	0.18	0.32	0.32	0.90	0.20	0.20	0.20	0.36	0.36	1.00	0.24	0.24	0.24	0.43	0.43	1.00

APPENDIX J—Development Complexity Factors

For this study, Development Complexity Factors were used to scale the relative effort required as compared to the level required for the reference aircraft. These tables show the overall composite effect on each subsystem based on the underlying technologies employed for the deployment scenario. These factors were determined by the SMEs. As the model is probabilistic based, these parameters represent the triangular distribution (low, most likely, high values).

TABLE J-1 – SA DEVELOPMENT COMPLEXITY FACTORS

	Low						Most Likely						High					
	2024			2034			2024			2034			2024			2034		
	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A
Air Vehicle																		
Airframe Integ.	0.90	1.29	1.40	1.34	1.43	1.57	1.00	1.43	1.55	1.49	1.59	1.74	1.10	1.72	2.02	1.64	1.91	2.26
Airframe																		
Fuselage	1.70	2.89	3.10	2.89	3.10	3.27	2.00	3.40	3.65	3.40	3.65	3.85	2.50	4.42	4.93	4.25	4.75	5.20
Wing																		
Structure Box	2.47	3.66	4.38	3.66	4.51	5.79	2.90	4.30	5.15	4.30	5.30	6.81	3.63	5.59	6.95	5.38	6.89	9.19
Flaps	2.04	3.06	3.44	3.44	3.66	4.29	2.40	3.60	4.05	4.05	4.30	5.05	3.00	4.68	5.47	5.06	5.59	6.82
Slats	1.66	2.68	2.76	2.85	2.93	3.10	1.95	3.15	3.25	3.35	3.45	3.65	2.44	4.10	4.39	4.19	4.49	4.93
Spoilers	1.66	2.47	2.76	2.85	2.93	3.10	1.95	2.90	3.25	3.35	3.45	3.65	2.44	3.77	4.39	4.19	4.49	4.93
Ailerons	2.04	2.85	3.15	3.23	3.32	3.91	2.40	3.35	3.70	3.80	3.90	4.60	3.00	4.36	5.00	4.75	5.07	6.21
Winglets	1.06	2.68	2.76	2.68	2.76	2.93	1.25	3.15	3.25	3.15	3.25	3.45	1.56	4.10	4.39	3.94	4.23	4.66
Empennage																		
Stabilizer	1.66	3.19	3.61	3.36	3.66	3.70	1.95	3.75	4.25	3.95	4.30	4.35	2.44	4.88	5.74	4.94	5.59	5.87
Fin	1.66	3.19	3.61	3.36	3.66	3.70	1.95	3.75	4.25	3.95	4.30	4.35	2.44	4.88	5.74	4.94	5.59	5.87
Landing Gear	1.06	1.70	1.70	1.49	1.70	1.70	1.25	2.00	2.00	1.75	2.00	2.00	1.56	2.60	2.70	2.19	2.60	2.70
Propulsion																		
Engine																		
Core	1.02	1.19	1.53	1.15	1.53	2.21	1.20	1.40	1.80	1.35	1.80	2.60	1.50	1.82	2.43	1.69	2.34	3.51
Pylon	1.49	1.96	1.96	1.96	1.96	1.96	1.75	2.30	2.30	2.30	2.30	2.30	2.19	2.99	3.11	2.88	2.99	3.11
Nacelle	1.93	2.66	3.08	3.04	3.15	3.36	2.28	3.13	3.63	3.58	3.70	3.95	2.84	4.06	4.89	4.47	4.81	5.33
Fuel System	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Systems																		
Aux Power Unit	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Surface Controls	2.10	2.75	2.85	2.75	2.95	3.40	2.25	2.90	3.00	2.90	3.10	3.55	2.50	3.15	3.25	3.15	3.35	3.80
Hydraulics	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Electrical	1.30	1.30	1.30	1.30	1.30	1.30	1.45	1.45	1.45	1.45	1.45	1.45	1.70	1.70	1.70	1.70	1.70	1.70
Furnishings	1.00	0.95	0.95	0.95	1.05	1.10	1.00	1.10	1.10	1.10	1.20	1.25	1.00	1.35	1.35	1.35	1.45	1.50
Air Conditioning	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Avionics	1.30	1.30	1.30	1.30	1.30	1.30	1.45	1.45	1.45	1.45	1.45	1.45	1.70	1.70	1.70	1.70	1.70	1.70
Misc Systems	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

TABLE J-2 – STA DEVELOPMENT COMPLEXITY FACTORS

	Low						Most Likely						High					
	2024			2034			2024			2034			2024			2034		
	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A
Air Vehicle																		
Airframe Integ.	0.90	1.27	1.46	1.35	1.49	1.62	1.00	1.41	1.62	1.50	1.66	1.80	1.10	1.69	2.11	1.64	1.99	2.34
Airframe																		
Fuselage	1.70	2.72	3.10	2.89	3.10	3.27	2.00	3.20	3.65	3.40	3.65	3.85	2.50	4.16	4.93	4.25	4.93	5.20
Wing																		
Structure Box	2.08	3.36	4.42	3.53	4.55	5.79	2.45	3.95	5.20	4.15	5.35	6.81	3.06	5.14	7.02	5.19	7.22	9.19
Flaps	2.04	2.89	3.57	3.23	3.78	4.42	2.40	3.40	4.20	3.80	4.45	5.20	3.00	4.42	5.67	4.75	6.01	7.02
Slats	1.66	2.51	2.89	2.85	3.06	3.23	1.95	2.95	3.40	3.35	3.60	3.80	2.44	3.84	4.59	4.19	4.86	5.13
Spoilers	1.66	2.30	2.89	2.64	3.06	3.23	1.95	2.70	3.40	3.10	3.60	3.80	2.44	3.51	4.59	3.88	4.86	5.13
Ailerons	2.04	2.68	3.27	3.02	3.44	4.04	2.40	3.15	3.85	3.55	4.05	4.75	3.00	4.10	5.20	4.44	5.47	6.41
Winglets	1.19	2.64	2.76	2.68	2.76	2.93	1.40	3.10	3.25	3.15	3.25	3.45	1.75	4.03	4.39	3.94	4.39	4.66
Empennage																		
Stabilizer	1.66	3.02	3.74	3.36	3.78	3.83	1.95	3.55	4.40	3.95	4.45	4.50	2.44	4.62	5.94	4.94	6.01	6.08
Fin	1.66	3.02	3.74	3.36	3.78	3.83	1.95	3.55	4.40	3.95	4.45	4.50	2.44	4.62	5.94	4.94	6.01	6.08
Landing Gear	1.06	1.70	1.83	1.49	1.83	1.83	1.25	2.00	2.15	1.75	2.15	2.15	1.56	2.60	2.90	2.19	2.90	2.90
Propulsion																		
Engine																		
Core	1.02	1.15	1.62	1.15	1.62	1.96	1.20	1.35	1.90	1.35	1.90	2.30	1.50	1.76	2.57	1.69	2.57	3.11
Pylon	1.49	1.96	1.96	1.96	1.96	1.96	1.75	2.30	2.30	2.30	2.30	2.30	2.19	2.99	3.11	2.88	3.11	3.11
Nacelle	1.93	2.66	3.08	3.04	3.15	3.36	2.28	3.13	3.63	3.58	3.70	3.95	2.84	4.06	4.89	4.47	5.00	5.33
Fuel System	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Systems																		
Aux Power Unit	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Surface Controls	1.65	2.75	2.55	2.47	2.64	3.02	1.80	2.90	3.00	2.90	3.10	3.55	2.05	3.15	4.05	3.63	4.19	4.79
Hydraulics	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Electrical	1.30	1.30	1.23	1.23	1.23	1.23	1.45	1.45	1.45	1.45	1.45	1.45	1.70	1.70	1.96	1.81	1.96	1.96
Furnishings	1.00	0.95	0.94	0.94	1.02	1.06	1.00	1.10	1.10	1.10	1.20	1.25	1.00	1.35	1.49	1.38	1.62	1.69
Air Conditioning	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Avionics	1.30	1.30	1.30	1.23	1.23	1.23	1.45	1.45	1.45	1.45	1.45	1.45	1.70	1.70	1.70	1.81	1.96	1.96
Misc Systems	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

TABLE J-3 – RJ DEVELOPMENT COMPLEXITY FACTORS

	Low						Most Likely						High					
	2024			2034			2024			2034			2024			2034		
	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A
Air Vehicle																		
Airframe Integ.	0.90	1.25	1.35	1.27	1.36	1.45	1.00	1.39	1.50	1.41	1.51	1.61	1.10	1.66	1.95	1.55	1.81	2.09
Airframe																		
Fuselage	1.70	2.72	2.93	2.72	2.93	3.10	2.00	3.20	3.45	3.20	3.45	3.65	2.50	4.16	4.66	4.00	4.66	5.11
Wing																		
Structure Box	2.25	3.27	3.95	3.27	3.95	4.94	2.65	3.85	4.65	3.85	4.65	5.81	3.31	5.01	6.28	4.81	6.28	8.13
Flaps	1.66	2.68	3.06	2.89	3.10	3.32	1.95	3.15	3.60	3.40	3.65	3.90	2.44	4.10	4.86	4.25	4.93	5.46
Slats	1.66	2.68	2.76	2.68	2.76	2.93	1.95	3.15	3.25	3.15	3.25	3.45	2.44	4.10	4.39	3.94	4.39	4.83
Spoilers	1.66	2.47	2.76	2.68	2.76	2.93	1.95	2.90	3.25	3.15	3.25	3.45	2.44	3.77	4.39	3.94	4.39	4.83
Ailerons	1.66	2.47	2.76	2.68	2.76	2.93	1.95	2.90	3.25	3.15	3.25	3.45	2.44	3.77	4.39	3.94	4.39	4.83
Winglets	1.06	2.68	2.76	2.68	2.76	2.93	1.25	3.15	3.25	3.15	3.25	3.45	1.56	4.10	4.39	3.94	4.39	4.83
Empennage																		
Stabilizer	1.66	2.68	2.89	2.68	2.89	2.89	1.95	3.15	3.40	3.15	3.40	3.40	2.44	4.10	4.59	3.94	4.59	4.76
Fin	1.66	2.68	2.89	2.68	2.89	2.89	1.95	3.15	3.40	3.15	3.40	3.40	2.44	4.10	4.59	3.94	4.59	4.76
Landing Gear	1.06	1.53	1.53	1.32	1.53	1.53	1.25	1.80	1.80	1.55	1.80	1.80	1.56	2.34	2.43	1.94	2.43	2.52

	Low						Most Likely						High					
	2024			2034			2024			2034			2024			2034		
	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A
Propulsion																		
Engine	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Core	1.02	1.19	1.53	1.15	1.53	2.21	1.20	1.40	1.80	1.35	1.80	2.60	1.50	1.82	2.43	1.69	2.43	3.64
Pylon	1.49	1.79	1.79	1.79	1.79	1.79	1.75	2.10	2.10	2.10	2.10	2.10	2.19	2.73	2.84	2.63	2.84	2.94
Nacelle	1.93	2.66	3.08	3.04	3.15	3.36	2.28	3.13	3.63	3.58	3.70	3.95	2.84	4.06	4.89	4.47	5.00	5.53
Fuel System	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Systems																		
Aux Power Unit	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Surface Controls	1.30	1.55	1.65	1.55	1.70	1.75	1.45	1.70	1.80	1.70	1.85	1.90	1.70	1.95	2.05	1.95	2.10	2.15
Hydraulics	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Electrical	1.30	1.30	1.30	1.30	1.30	1.30	1.45	1.45	1.45	1.45	1.45	1.45	1.70	1.70	1.70	1.70	1.70	1.70
Furnishings	1.00	0.95	0.95	0.95	1.05	1.10	1.00	1.10	1.10	1.10	1.20	1.25	1.00	1.35	1.35	1.35	1.45	1.50
Air Conditioning	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Avionics	1.30	1.30	1.30	1.30	1.30	1.30	1.45	1.45	1.45	1.45	1.45	1.45	1.70	1.70	1.70	1.70	1.70	1.70
Misc Systems	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

APPENDIX K—Production Complexity Factors

For the study, Production Complexity Factors were used to scale the relative effort required as compared to the level required for the reference aircraft. These tables show the overall composite effect on each subsystem based on the underlying technologies employed for the deployment scenario (E = evolutionary, M = moderate, A = aggressive). These factors were determined by the SMEs. As the model is probabilistic based, these parameters represent the triangular distribution (low, most likely, high values).

TABLE K-1 – SA PRODUCTION COMPLEXITY FACTORS

	Low						Most Likely						High					
	2024			2034			2024			2034			2024			2034		
	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A
Air Vehicle																		
Vehicle Integration	0.81	0.87	0.89	0.89	0.90	0.94	0.90	0.97	0.99	0.99	1.00	1.05	0.99	1.16	1.29	1.09	1.20	1.36
Airframe																		
Fuselage	0.60	0.75	0.73	0.75	0.73	0.73	0.70	0.85	0.83	0.85	0.83	0.83	0.85	1.10	1.08	1.00	1.08	1.18
Wing																		
Structure Box	0.66	0.81	0.79	0.81	0.79	0.99	0.76	0.91	0.89	0.91	0.89	1.09	0.91	1.16	1.14	1.06	1.14	1.44
Flaps	0.63	0.80	0.91	0.90	0.94	1.16	0.73	0.90	1.01	1.00	1.04	1.26	0.88	1.15	1.26	1.15	1.29	1.61
Slats	0.60	0.74	0.74	0.79	0.78	0.78	0.70	0.84	0.84	0.89	0.88	0.88	0.85	1.09	1.09	1.04	1.13	1.23
Spoilers	0.60	0.67	0.74	0.79	0.78	0.78	0.70	0.77	0.84	0.89	0.88	0.88	0.85	1.02	1.09	1.04	1.13	1.23
Ailerons	0.63	0.70	0.77	0.80	0.79	1.04	0.73	0.80	0.87	0.90	0.89	1.14	0.88	1.05	1.12	1.05	1.14	1.49
Winglets	0.80	0.74	0.74	0.74	0.73	0.73	0.90	0.84	0.84	0.84	0.83	0.83	1.05	1.09	1.09	0.99	1.08	1.18
Empennage																		
Stabilizer	0.62	0.79	0.80	0.81	0.80	0.79	0.72	0.89	0.90	0.91	0.90	0.89	0.87	1.14	1.15	1.06	1.15	1.24
Fin	0.62	0.79	0.80	0.81	0.80	0.79	0.72	0.89	0.90	0.91	0.90	0.89	0.87	1.14	1.15	1.06	1.15	1.24
Landing Gear	0.85	1.02	1.02	1.02	1.02	1.02	0.95	1.12	1.12	1.12	1.12	1.12	1.10	1.37	1.37	1.27	1.37	1.47
Propulsion																		
Engine																		
Core	0.92	0.94	1.00	0.94	1.00	1.30	1.02	1.04	1.10	1.04	1.10	1.40	1.17	1.29	1.35	1.19	1.35	1.75
Pylon	0.75	0.79	0.79	0.79	0.79	0.79	0.85	0.89	0.89	0.89	0.89	0.89	1.00	1.14	1.14	1.04	1.14	1.24
Nacelle	0.50	0.64	0.71	0.71	0.70	0.66	0.60	0.74	0.81	0.81	0.80	0.76	0.75	0.99	1.06	0.96	1.05	1.11
Fuel System	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Systems																		
Aux Power Unit	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Surface Controls	1.25	1.50	1.65	1.50	1.65	1.85	1.35	1.60	1.75	1.60	1.75	1.95	1.50	1.85	2.00	1.75	2.00	2.30
Hydraulics	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Electrical	1.05	1.05	1.05	1.05	1.05	1.05	1.15	1.15	1.15	1.15	1.15	1.15	1.30	1.40	1.40	1.30	1.40	1.50
Furnishings	0.90	0.80	0.80	0.80	0.80	0.77	1.00	0.90	0.90	0.90	0.90	0.87	1.15	1.15	1.15	1.05	1.15	1.22
Air Conditioning	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Avionics	1.05	1.05	1.05	1.05	1.05	1.05	1.15	1.15	1.15	1.15	1.15	1.15	1.30	1.40	1.40	1.30	1.40	1.50
Misc Systems	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

TABLE K-2 – STA PRODUCTION COMPLEXITY FACTORS

	Low						Most Likely						High					
	2024			2034			2024			2034			2024			2034		
	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A
Air Vehicle																		
Vehicle Integration	0.80	0.87	0.91	0.88	0.92	0.98	0.89	0.97	1.01	0.98	1.03	1.09	0.98	1.16	1.31	1.08	1.23	1.42
Airframe																		
Fuselage	0.60	0.75	0.74	0.75	0.76	0.79	0.70	0.85	0.84	0.85	0.86	0.89	0.85	1.10	1.19	1.00	1.11	1.24
Wing																		
Structure Box	0.63	0.79	0.94	0.79	1.00	1.24	0.73	0.89	1.04	0.89	1.10	1.34	0.88	1.14	1.39	1.04	1.35	1.69
Flaps	0.63	0.80	0.95	0.83	0.99	1.31	0.73	0.90	1.05	0.93	1.09	1.41	0.88	1.15	1.40	1.08	1.34	1.76
Slats	0.60	0.74	0.77	0.79	0.83	0.85	0.70	0.84	0.87	0.89	0.93	0.95	0.85	1.09	1.22	1.04	1.18	1.30
Spoilers	0.60	0.67	0.77	0.72	0.83	0.85	0.70	0.77	0.87	0.82	0.93	0.95	0.85	1.02	1.22	0.97	1.18	1.30
Ailerons	0.63	0.70	0.80	0.73	0.84	1.11	0.73	0.80	0.90	0.83	0.94	1.21	0.88	1.05	1.25	0.98	1.19	1.56
Winglets	0.81	0.75	0.75	0.74	0.76	0.78	0.91	0.85	0.85	0.84	0.86	0.88	1.06	1.10	1.20	0.99	1.11	1.23
Empennage																		
Stabilizer	0.62	0.79	0.83	0.81	0.85	0.87	0.72	0.89	0.93	0.91	0.95	0.97	0.87	1.14	1.28	1.06	1.20	1.32
Fin	0.62	0.79	0.83	0.81	0.85	0.87	0.72	0.89	0.93	0.91	0.95	0.97	0.87	1.14	1.28	1.06	1.20	1.32
Landing Gear	0.85	1.02	1.04	1.02	1.06	1.05	0.95	1.12	1.14	1.12	1.16	1.15	1.10	1.37	1.49	1.27	1.41	1.50
Propulsion																		
Engine																		
Core	0.92	0.94	1.00	0.95	1.00	1.30	1.02	1.00	1.10	1.05	1.10	1.40	1.17	1.29	1.45	1.20	1.35	1.75
Pylon	0.75	0.79	0.79	0.79	0.80	0.80	0.85	0.89	0.89	0.89	0.90	0.90	1.00	1.14	1.24	1.04	1.15	1.25
Nacelle	0.50	0.64	0.72	0.71	0.71	0.74	0.60	0.74	0.82	0.81	0.81	0.84	0.75	0.99	1.17	0.96	1.06	1.19
Fuel System	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Systems																		
Aux Power Unit	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Surface Controls	1.15	1.50	1.65	1.50	1.65	1.85	1.25	1.60	1.75	1.60	1.75	1.95	1.40	1.85	2.10	1.75	2.00	2.30
Hydraulics	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Electrical	1.05	1.05	1.05	1.05	1.05	1.05	1.15	1.15	1.15	1.15	1.15	1.15	1.30	1.40	1.50	1.30	1.40	1.50
Furnishings	0.90	0.80	0.80	0.80	0.80	0.80	1.00	0.90	0.90	0.90	0.90	0.90	1.15	1.15	1.25	1.05	1.15	1.25
Air Conditioning	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Avionics	1.05	1.05	1.05	1.05	1.05	1.05	1.15	1.15	1.15	1.15	1.15	1.15	1.30	1.40	1.50	1.30	1.40	1.50
Misc Systems	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

TABLE K-3 – RJ PRODUCTION COMPLEXITY FACTORS

	Low						Most Likely						High					
	2024			2034			2024			2034			2024			2034		
	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A
Air Vehicle																		
Vehicle Integration	0.81	0.86	0.88	0.88	0.89	0.90	0.90	0.96	0.98	0.97	0.99	1.00	0.99	1.15	1.27	1.07	1.19	1.30
Airframe																		
Fuselage	0.60	0.74	0.72	0.74	0.75	0.75	0.70	0.84	0.82	0.84	0.85	0.85	0.85	1.09	1.17	0.99	1.15	1.25
Wing																		
Structure Box	0.66	0.80	0.78	0.80	0.81	0.76	0.76	0.90	0.88	0.90	0.91	0.86	0.91	1.15	1.23	1.05	1.21	1.26
Flaps	0.60	0.77	0.88	0.84	0.91	0.88	0.70	0.87	0.98	0.94	1.01	0.98	0.85	1.12	1.33	1.09	1.31	1.38
Slats	0.60	0.74	0.74	0.74	0.76	0.76	0.70	0.84	0.84	0.84	0.86	0.86	0.85	1.09	1.19	0.99	1.16	1.26
Spoilers	0.60	0.67	0.74	0.74	0.76	0.76	0.70	0.77	0.84	0.84	0.86	0.86	0.85	1.02	1.19	0.99	1.16	1.26
Ailerons	0.60	0.67	0.74	0.74	0.76	0.76	0.70	0.77	0.84	0.84	0.86	0.86	0.85	1.02	1.19	0.99	1.16	1.26
Winglets	0.80	0.74	0.74	0.74	0.76	0.76	0.90	0.84	0.84	0.84	0.86	0.86	1.05	1.09	1.19	0.99	1.16	1.26
Empennage																		
Stabilizer	0.62	0.74	0.73	0.74	0.76	0.75	0.72	0.84	0.83	0.84	0.86	0.85	0.87	1.09	1.18	0.99	1.16	1.25
Fin	0.62	0.74	0.73	0.74	0.76	0.75	0.72	0.84	0.83	0.84	0.86	0.85	0.87	1.09	1.18	0.99	1.16	1.25
Landing Gear	0.85	1.00	1.00	1.00	1.01	1.01	0.95	1.10	1.10	1.10	1.11	1.11	1.10	1.35	1.45	1.25	1.41	1.51

	Low						Most Likely						High					
	2024			2034			2024			2034			2024			2034		
	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A	E	M	A
Propulsion																		
Engine																		
Core	0.92	0.94	1.00	0.94	1.00	1.30	1.02	1.04	1.10	1.04	1.10	1.40	1.17	1.29	1.45	1.19	1.40	1.80
Pylon	0.75	0.77	0.77	0.77	0.78	0.78	0.85	0.87	0.87	0.87	0.88	0.88	1.00	1.12	1.22	1.02	1.18	1.28
Nacelle	0.50	0.64	0.71	0.71	0.73	0.69	0.60	0.74	0.81	0.81	0.83	0.79	0.75	0.99	1.16	0.96	1.13	1.19
Fuel System	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Systems																		
Aux Power Unit	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Surface Controls	1.05	1.20	1.25	1.20	1.25	1.30	1.15	1.30	1.35	1.30	1.35	1.40	1.30	1.55	1.70	1.45	1.65	1.80
Hydraulics	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Electrical	1.05	1.05	1.05	1.05	1.05	1.05	1.15	1.15	1.15	1.15	1.15	1.15	1.30	1.40	1.50	1.30	1.45	1.55
Furnishings	0.90	0.80	0.80	0.80	0.80	0.77	1.00	0.90	0.90	0.90	0.90	0.87	1.15	1.15	1.25	1.05	1.20	1.27
Air Conditioning	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Avionics	1.05	1.05	1.05	1.05	1.05	1.05	1.15	1.15	1.15	1.15	1.15	1.15	1.30	1.40	1.50	1.30	1.45	1.55
Misc Systems	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

APPENDIX L—Derivation of Composite Material Fraction for Reference Aircraft

Tables L-1 displays the application of the CMFs at the WBS level for A320-200, 777-200ER, and the Embraer 190AR. Global Express Business Jet. The resulting total structure composite fraction for the A320 is 14.1%, the results for the 777-200ER are at 12.1%, the results for E190 are 11.6%. Given that composites are used in almost all of the same areas on both the A320 and 777-200ER aircraft, the composite percentages are expected to be close.

input values

TABLE L-1 – ESTIMATED COMPOSITE MATERIAL WEIGHT FRACTION

WBS Level 1	2	3	4	A320-200 (SA) comp wt fraction	777-200ER (STA) comp wt fraction	E190 (RJ) comp wt fraction
STRUCTURES				0.141	0.121	0.105
	wing group			0.179	0.125	0.142
		struct box		0.1027	0.09029	0.0582
			fairings	0.80	0.80	0.80
			TE panels	0.85	0.85	0.00
			MLG doors	0.80	0.80	0.80
			J-nose (inboard LE)	0.80	0.00	0.00
			center box	0.75	0.00	0.00
			ribs	0.75	0.00	0.00
			Outer box	0.75	0.00	0.00
			other			
		flaps		0.50	0.50	0.50
		slats		0.50	0.00	0.00
		spoilers		0.50	0.50	0.50
		ailerons		0.50	0.50	0.50
		winglets		0.60	0.00	0.60
	fuselage group			0.0625	0.0594	0.0619
		radome		0.90	0.90	0.90
		NLG doors		0.80	0.80	0.80
		floor beams		0.85	0.85	0.85
		keel beam		0.75	0.00	0.00
		cross beams		0.75	0.00	0.00
		rear pressure bulkhead		0.85	0.00	0.00
		rear un-press. fus.		0.75	0.00	0.00
		upper skin		0.75	0.00	0.00
		full skin & frames		0.75	0.00	0.00
		tail cone		0.85	0.00	0.00
		other				
	tail group			0.715	0.715	0.197
		Stabilizer		0.7150	0.715	2.35
			elevators	0.50	0.50	0.50
			LE & TE panels	0.85	0.85	0.85
			struct box (dry)	0.80	0.80	0.00
			struct box (wet)	0.80	0.80	0.00
			other			

WBS Level 1 2 3 4	A320-200 (SA) comp wt fraction	777-200ER (STA) comp wt fraction	E190 (RJ) comp wt fraction
Fin (ind. dorsal)	0.7150	0.7150	0.1500
rudder	0.50	0.50	0.50
LE & TE panels	0.85	0.85	0.00
struct box	0.80	0.80	0.00
other			
undercarriage	0.00	0.00	0.00
PROPULSION	0.1029	0.1248	0.1496
dry engines total	0.00	0.00	0.00
nacelles total	0.50	0.05	0.50
pylons total	0.05	0.05	0.00

APPENDIX M—Deployment Scenario Composite Material Fraction

The Aerodynamic & Structures Subject Matter Experts (SME) identified the composite percentage for each Deployment Scenarios (DS) for the Single Aisle, Small Twin Aisle, and Regional Jet aircraft. The results are detailed in the tables below. As the model is probabilistic based, these parameters represent the triangular distribution (low, most likely, high values).

TABLE M-1 – SA 2024 COMPOSITE PERCENTAGE

	2024 Evolutionary				2024 Stretch				2024 Aggressive			
	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.
Air Vehicle												
Airframe												
Fuselage	83%	85%	87%	Med	87%	89%	91%	Med	91%	93%	95%	Low
Wing												
Structure Box	92%	94%	96%	Med	95%	97%	99%	Med	98%	100%	100%	High
Flaps	95%	97%	99%	Med	98%	100%	100%	Med	98%	100%	100%	High
Slats	95%	97%	99%	Med	98%	100%	100%	Med	98%	100%	100%	High
Spoilers	95%	97%	99%	Med	98%	100%	100%	Med	98%	100%	100%	High
Ailerons	95%	97%	99%	Med	98%	100%	100%	Med	98%	100%	100%	High
Winglets	96%	98%	100%	Med	98%	100%	100%	Med	98%	100%	100%	High
Empennage												
Stabilizer	95%	97%	99%	Med	98%	100%	100%	Med	98%	100%	100%	High
Fin	95%	97%	99%	Med	98%	100%	100%	Med	98%	100%	100%	High
Landing Gear		2%		Med	3%	5%	7%	Low	6%	8%	10%	Low
Propulsion												
Engine												
Nacelle	93%	95%	97%	Med	98%	100%	100%	Med	98%	100%	100%	High
Pylon	10%	12%	14%	Med	14%	16%	18%	Low	18%	20%	22%	Low
Core	20%	25%	30%	Med	25%	30%	35%	Med	30%	35%	40%	Med

TABLE M-2 – SA 2034 COMPOSITE PERCENTAGE

	2034 Evolutionary				2034 Stretch				2034 Aggressive			
	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.
Air Vehicle												
Airframe												
Fuselage	97%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Wing												
Structure Box	97%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Flaps	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Slats	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Spoilers	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Ailerons	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Winglets	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Empennage												
Stabilizer	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Fin	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Landing Gear	13%	15%	17%	Low	17%	19%	21%	Low	21%	23%	25%	Low

	2034 Evolutionary				2034 Stretch				2034 Aggressive			
	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.
Propulsion												
Engine												
Nacelle	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Pylon	23%	25%	27%	Low	27%	29%	31%	Low	31%	33%	35%	Low
Core	20%	25%	30%	Med	35%	40%	45%	Med	45%	50%	55%	Med

TABLE M-3 – STA 2024 COMPOSITE PERCENTAGE

	2024 Evolutionary				2024 Stretch				2024 Aggressive			
	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.
Air Vehicle												
Airframe												
Fuselage	83%	85%	87%	Med	87%	89%	91%	Med	91%	93%	95%	Low
Wing												
Structure Box	92%	94%	96%	Med	95%	97%	99%	Med	98%	100%	100%	High
Flaps	95%	97%	99%	Med	98%	100%	100%	Med	98%	100%	100%	High
Slats	95%	97%	99%	Med	98%	100%	100%	Med	98%	100%	100%	High
Spoilers	95%	97%	99%	Med	98%	100%	100%	Med	98%	100%	100%	High
Ailerons	95%	97%	99%	Med	98%	100%	100%	Med	98%	100%	100%	High
Winglets	96%	98%	100%	Med	98%	100%	100%	High	98%	100%	100%	High
Empennage												
Stabilizer	97%	99%	100%	Med	98%	100%	100%	High	98%	100%	100%	High
Fin	97%	99%	100%	Med	98%	100%	100%	High	98%	100%	100%	High
Landing Gear	1%	2%	3%	Med	3%	5%	7%	Low	6%	8%	10%	Low
Propulsion												
Engine												
Nacelle	93%	95%	97%	Med	98%	100%	100%	Med	98%	100%	100%	High
Pylon	10%	12%	14%	Med	14%	16%	18%	Low	18%	20%	22%	Low
Core	20%	25%	30%	Med	25%	30%	35%	Med	30%	25%	40%	Med

TABLE M-4 – STA 2034 COMPOSITE PERCENTAGE

	2034 Evolutionary				2034 Stretch				2034 Aggressive			
	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.
Air Vehicle												
Airframe												
Fuselage	97%	100%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Wing												
Structure Box	97%	100%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Flaps	98%	100%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Slats	98%	100%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Spoilers	98%	100%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Ailerons	98%	100%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Winglets	98%	100%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Empennage												
Stabilizer	98%	100%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Fin	98%	100%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Landing Gear	13%	15%	17%	Low	17%	19%	21%	Low	21%	23%	25%	Low

	2034 Evolutionary				2034 Stretch				2034 Aggressive			
	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.
Propulsion												
Engine												
Nacelle	98%	100%	100%	High	98%	99%	100%	High	98%	100%	100%	High
Pylon	25%	30%	35%	Low	27%	29%	31%	Low	31%	33%	35%	Low
Core	24%	30%	35%	Med	35%	40%	45%	Med	45%	50%	55%	Med

TABLE M-5 – RJ 2024 COMPOSITE PERCENTAGE

	2024 Evolutionary				2024 Stretch				2024 Aggressive			
	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.
Air Vehicle												
Airframe												
Fuselage	83%	85%	87%	Med	87%	89%	91%	Med	91%	93%	95%	Low
Wing												
Structure Box	92%	94%	96%	Med	95%	97%	99%	Med	98%	100%	100%	High
Flaps	95%	97%	99%	Med	98%	100%	100%	Med	98%	100%	100%	High
Slats	95%	97%	100%	Med	98%	100%	100%	Med	98%	100%	100%	High
Spoilers	95%	97%	99%	Med	98%	100%	100%	Med	98%	100%	100%	High
Ailerons	95%	97%	99%	Med	98%	100%	100%	Med	98%	100%	100%	High
Winglets	96%	98%	100%	Med	98%	100%	100%	Med	98%	100%	100%	High
Empennage												
Stabilizer	97%	99%	100%	Med	98%	100%	100%	Med	98%	100%	100%	High
Fin	97%	99%	100%	Med	98%	100%	100%	Med	98%	100%	100%	High
Landing Gear	0%	2%	4%	Med	3%	5%	7%	Low	6%	8%	10%	Low
Propulsion												
Engine												
Nacelle	93%	95%	97%	Med	98%	100%	100%	Med	98%	100%	100%	High
Pylon	10%	12%	14%	Med	14%	16%	18%	Low	18%	20%	22%	Low
Core	20%	25%	30%	Med	25%	30%	35%	Med	30%	35%	40%	Med

TABLE M-6 – RJ 2034 COMPOSITE PERCENTAGE

	2034 Evolutionary				2034 Stretch				2034 Aggressive			
	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.	Low	Most Likely	High	Conf.
Air Vehicle												
Airframe												
Fuselage	97%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Wing												
Structure Box	97%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Flaps	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Slats	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Spoilers	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Ailerons	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Winglets	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Empennage												
Stabilizer	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Fin	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Landing Gear	13%	15%	17%	Low	17%	19%	21%	Low	21%	23%	25%	Low
Propulsion												
Engine												
Nacelle	98%	99%	100%	High	98%	100%	100%	High	98%	100%	100%	High
Pylon	23%	25%	27%	Low	27%	29%	31%	Low	31%	33%	35%	Low
Core	20%	25%	30%	Med	35%	40%	45%	Med	45%	50%	55%	Med

APPENDIX N—Technology Maturation Cost Estimation Model Inputs

The model was originally established to estimate the costs of maturing technologies beginning with TRL 1. The technologies estimated for this study typically began at TRL Level 4 or later. The following provides information on the work effort required to progress through each TRL level. The analysis was done to identify from a labor and material build-up perspective the overall cost to progress through each TRL. The term Time Dependent (TD) refers to costs that are increase as the duration increases, meaning the total cost is dependent on a burn-rate and the time required to do the effort. The term Time Independent (TI) refers to costs that are not dependent on the duration, like material purchases.

TRL Level 4

DEVELOP DOCUMENTATION AND VERIFICATION PLANS—a 10% TI/90% TD split was used because there is always the aspect of upper levels of engineering, including safety and quality, having to review and approve the documentation and verification plans. This review cycle is typically presented as a percentage of the overall effort.

DEVELOP UNIQUE MANUFACTURING/FABRICATION NEEDS—a 30% TI/70% TD split was used because, as the manufacturer works to develop unique manufacturing tooling, some materials will be needed, including tooling, to ensure that their needs can be met once the program moves into full-rate production.

EVOLVE BASELINE INTO PRODUCT SPECS—a 10% TI/90% TD split was used because there is always the aspect of upper levels of engineering, including safety and quality, having to review and approve the documentation and verification plans. This review cycle is typically presented as a percentage of the overall effort.

DEVELOP DESIGN/INITIAL DRAWINGS—a 20% TI/80% TD split was used because the review cycle of the design/drawings includes significant oversight and review to ensure that the technology is ready to move to the development of the initial prototype.

TRL Level 5

DEVELOP INITIAL PROTOTYPES—a 50% TI/50% TD split was used because of the need to procure materials to develop the initial prototype, as well as ensuring that quality engineering is supporting the efforts throughout. Typically, quality engineering is a percentage of the overall effort, not a direct bill like other engineering specialties.

DETAILED ANALYSIS (MODELING AND SIMULATION)—a 50% TI/50% TD split was used because of the need to utilize lab and simulator time in order to analyze the initial prototype, as well as ensuring that quality engineering is supporting the efforts throughout. Typically, quality engineering is a percentage of the overall effort, not a direct bill like other engineering specialties.

ORDER MATERIAL—100% TI cost was used to account for any material that would be necessary to build models and/or test articles. The material costs were derived using the Cost Estimating Relationships (CERs) for specific aircraft components and then prorated, if necessary, according to the design (for example, the wing CER was divided by two, as testing would only require one wing, not both).

CRITICAL DESIGN REVIEW (CDR)—a 10% TI/90% TD split was used because, as the manufacturer goes into CDR, there are a series of reviews that must be accomplished in order to proceed. These reviews are typically presented as a percentage of the overall effort.

TRL Level 6

FABRICATE/ASSEMBLE/CODE TO PRODUCT SPECS—a 50% TI/50% TD split was used because of the need to procure materials to develop the initial prototype, as well as ensuring that quality engineering is supporting the efforts throughout. Typically, quality engineering is a percentage of the overall effort, not a direct bill like other engineering specialties.

DEVELOP SIMULATORS—a 50% TI/50% TD split was used because of the need to procure materials to develop the initial prototype, as well as ensuring that quality engineering is supporting the efforts throughout. Typically, quality engineering is a percentage of the overall effort, not a direct bill like other engineering specialties.

DEVELOP TEST PLANS AND VERIFICATION OPTIONS—a 10% TI/90% TD split was used because there is always the aspect of upper levels of engineering, including safety and quality, having to review and approve the documentation and verification plans. This review cycle is typically presented as a percentage of the overall effort.

TRL Level 7

INDIVIDUAL TEST AND EVALUATION—a 25% TI/75% TD split was used because of the need for the test instrumentation and equipment to be installed and uninstalled, as well as often rigid structure of component level testing. A higher ratio of TD costs were identified for this item due to the variable nature of testing, where the overall time for tests can increase or decrease based on the results of the testing.

INTEGRATED TEST AND EVALUATION—a 25% TI/75% TD split was used because of the need for the test instrumentation and equipment to be installed and uninstalled, as well as often rigid structure of integrated testing. A higher ratio of TD costs were identified for this item due to the variable nature of testing, where the overall time for tests can increase or decrease based on the results of the testing.

TEST READINESS REVIEW (TRR)—a 10% TI/90% TD split was used because, as the manufacturer goes into TRR, there are a series of reviews that must be accomplished in order to proceed. These reviews are typically presented as a percentage of the overall effort.

PRODUCTION READINESS REVIEW (PRR)—a 10% TI/90% TD split was used because, as the manufacturer goes into PRR, there are a series of reviews that must be accomplished in order to proceed. These reviews are typically presented as a percentage of the overall effort.

For technology maturation costs, the Subject Matter Experts (SME) provided the duration of the effort to mature the respective technology, the staffing or manpower required to achieve the target maturity, and the uncertainty associated with effort. These inputs created the notional project profile (using Microsoft

Project) and it was used as a basis to calculate the probabilistic schedule and cost (using the JACS MS Project Add-In). The results from JACS were used to aggregate the cost for the each of the scenario and aircraft types.

SMEs Input for Specific Technologies

Development and maturation costs for the engine/propulsion technologies are assumed to be captured by the engine CER that estimates the price of the engine on both thrust and Specific Fuel Consumption (SFC). Engine technologies are therefore not included as part of the technology maturation costs.

Tables N-1 through N-20 display inputs from the Aerodynamics & Structures SMEs for the technology maturation estimating effort in regards to required manpower and the timelines. The SMEs completed the tables beginning with the Technical Advisory Group (TAG) estimated current TRL level and completed through TRL 7. It was assumed that TRL 8 and 9 activities are included within the scope of System Development and are therefore captured as part of System Development costs as calculated by the underlying CERs. The technologies estimated for this study typically have a starting level no lower than TRL Level 4 and the technology maturation model estimates the cost to complete TRL 7, hence the tables have only reflect the level of activity for each technology based on the SME's assessment of their starting TRL level.

TABLE N-1 – IMPROVED AERO/TRANSONIC DESIGN (ANV-1)

TRl Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
6	Fabricate/Assemble/Code to Product Specs	5	20	Medium	50	200	Medium
	Develop Simulators	5	20	Medium	50	200	Medium
	Develop Test Plans & Verification Options	3	12	Medium	5	20	Medium
7	Individual Test & Evaluation	3	12	Medium	20	80	Medium
	Integrated Test & Evaluation	3	12	Medium	20	80	Medium
	Test Readiness Review	3	12	Medium	4	16	Medium
	Production Readiness Review	3	12	Medium	4	16	Medium

TABLE N-2 – VARIABLE CAMBER WITH EXISTING CONTROL SURFACES (ANV-3)

TRl Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
6	Fabricate/Assemble/Code to Product Specs	4	16	Medium	20	80	Medium
	Develop Simulators	4	16	Medium	20	80	Medium
	Develop Test Plans & Verification Options	3	12	Medium	5	20	Medium
7	Individual Test & Evaluation	2	8	Medium	10	40	Medium
	Integrated Test & Evaluation	2	8	Medium	10	40	Medium
	Test Readiness Review	2	8	Medium	3	12	Medium
	Production Readiness Review	2	8	Medium	3	12	Medium

TABLE N-3 – ADAPTIVE COMPLIANT TRAILING EDGE (ANV-4)

TRl Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
5	Develop Initial Prototypes	5	20	Medium	15	60	Medium
	Detailed Analysis (Modeling & Simulation)	4	16	Medium	10	40	Medium
	Critical Design Review	2	8	Medium	6	24	Medium

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
6	Fabricate/Assemble/Code to Product Specs	5	20	Medium	30	120	Medium
	Develop Simulators	5	20	Medium	30	120	Medium
	Develop Test Plans & Verification Options	4	16	Medium	10	40	Medium
7	Individual Test & Evaluation	3	12	Medium	20	80	Medium
	Integrated Test & Evaluation	3	12	Medium	20	80	Medium
	Test Readiness Review	3	12	Medium	6	24	Medium
	Production Readiness Review	3	12	Medium	6	24	Medium

TABLE N-4 – ACTIVE STABILITY CONTROL (ANV-5)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
4	Develop Documentation & Verification Plans	2	8	Medium	3	12	Medium
	Develop Unique Manufacturing/Fabrication Needs	2	8	Medium	3	12	Medium
	Evolve Baseline into Product Specs	3	12	Medium	3	12	Medium
	Develop Design/Initial Drawings	3	12	Medium	3	12	Medium
5	Develop Initial Prototypes	5	20	Medium	5	20	Medium
	Detailed Analysis (Modeling & Simulation)	10	40	Medium	10	40	Medium
	Critical Design Review	2	20	Medium	4	16	Medium
6	Fabricate/Assemble/Code to Product Specs	5	20	Medium	5	20	Medium
	Develop Simulators	10	40	Medium	10	40	Medium
	Develop Test Plans & Verification Options	5	20	Medium	10	40	Medium
7	Individual Test & Evaluation	5	20	Medium	10	40	Medium
	Integrated Test & Evaluation	10	40	Medium	10	40	Medium
	Test Readiness Review	5	20	Medium	5	20	Medium
	Production Readiness Review	5	20	Medium	5	20	Medium

TABLE N-5 – REDUCTION OF LOADS (ANV-6)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
4	Develop Documentation & Verification Plans	5	20	Medium	5	20	Medium
	Develop Unique Manufacturing/Fabrication Needs	5	20	Medium	5	20	Medium
	Evolve Baseline into Product Specs	6	24	Medium	5	20	Medium
	Develop Design/Initial Drawings	6	24	Medium	5	20	Medium
5	Develop Initial Prototypes	10	40	Medium	7.5	30	Medium
	Detailed Analysis (Modeling & Simulation)	10	40	Medium	10	40	Medium
	Critical Design Review	3	12	Medium	4	16	Medium
6	Fabricate/Assemble/Code to Product Specs	10	40	Medium	10	40	Medium
	Develop Simulators	20	80	Medium	10	40	Medium
	Develop Test Plans & Verification Options	5	20	Medium	5	20	Medium
7	Individual Test & Evaluation	10	40	Medium	5	20	Medium
	Integrated Test & Evaluation	10	40	Medium	5	20	Medium
	Test Readiness Review	10	40	Medium	5	20	Medium
	Production Readiness Review	10	40	Medium	5	20	Medium

TABLE N-6 – INCREASED WING SPAN (ANV-7)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
7	Individual Test & Evaluation	10	40	Medium	5	20	Medium
	Integrated Test & Evaluation	10	40	Medium	5	20	Medium
	Test Readiness Review	10	40	Medium	5	20	Medium
	Production Readiness Review	10	40	Medium	5	20	Medium

TABLE N-7 – ELECTRIC LANDING GEAR DRIVE SYSTEM (SYS-2)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
5	Develop Initial Prototypes	2	8	Medium	3	12	Medium
	Detailed Analysis (Modeling & Simulation)	1	4	Medium	3	12	Medium
	Critical Design Review	1	4	Medium	1	4	Medium
6	Fabricate/Assemble/Code to Product Specs	3	12	Medium	5	20	Medium
	Develop Simulators	1	4	Medium	1	4	Medium
	Develop Test Plans & Verification Options	1	4	Medium	1	4	Medium
7	Individual Test & Evaluation	1	4	Medium	2	8	Medium
	Integrated Test & Evaluation	1	4	Medium	2	8	Medium
	Test Readiness Review	1	4	Medium	2	8	Medium
	Production Readiness Review	1	4	Medium	2	8	Medium

TABLE N-8 – HYBRID LAMINAR FLOW ON EMPENNAGE (AV-2)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
4	Develop Documentation & Verification Plans	1.5	6	Medium	1.5	6	Medium
	Develop Unique Manufacturing/Fabrication Needs	2	8	Medium	1.5	6	Medium
	Evolve Baseline into Product Specs	1	4	Medium	2	8	Medium
	Develop Design/Initial Drawings	1.5	6	Medium	2.5	10	Medium
5	Develop Initial Prototypes	2	8	Medium	20	80	Medium
	Detailed Analysis (Modeling & Simulation)	2	8	Medium	10	40	Medium
	Critical Design Review	0.5	2	Medium	1	4	Medium
6	Fabricate/Assemble/Code to Product Specs	2	8	Medium	20	80	Medium
	Develop Simulators	2	8	Medium	20	80	Medium
	Develop Test Plans & Verification Options	1	4	Medium	2	8	Medium
7	Individual Test & Evaluation	1	4	Medium	10	40	Medium
	Integrated Test & Evaluation	1	4	Medium	10	40	Medium
	Test Readiness Review	1	4	Medium	2	8	Medium
	Production Readiness Review	1	4	Medium	2	8	Medium

TABLE N-9 – NATURAL LAMINAR FLOW ON WINGS (AV-3)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
5	Develop Initial Prototypes	4	16	Medium	40	160	Medium
	Detailed Analysis (Modeling & Simulation)	4	16	Medium	20	80	Medium
	Critical Design Review	1	4	Medium	2	8	Medium
6	Fabricate/Assemble/Code to Product Specs	4	16	Medium	40	160	Medium
	Develop Simulators	4	16	Medium	40	160	Medium
	Develop Test Plans & Verification Options	2	8	Medium	4	16	Medium
7	Individual Test & Evaluation	2	8	Medium	20	80	Medium
	Integrated Test & Evaluation	2	8	Medium	20	80	Medium
	Test Readiness Review	2	8	Medium	4	16	Medium
	Production Readiness Review	2	8	Medium	4	16	Medium

TABLE N-10 – HYBRID LAMINAR FLOW ON WINGS (AV-4)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
5	Develop Initial Prototypes	6	24	Medium	60	240	Medium
	Detailed Analysis (Modeling & Simulation)	6	24	Medium	30	120	Medium
	Critical Design Review	1.5	6	Medium	3	12	Medium

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
6	Fabricate/Assemble/Code to Product Specs	6	24	Medium	60	240	Medium
	Develop Simulators	6	24	Medium	60	240	Medium
	Develop Test Plans & Verification Options	4	16	Medium	6	24	Medium
7	Individual Test & Evaluation	3	12	Medium	30	120	Medium
	Integrated Test & Evaluation	3	12	Medium	30	120	Medium
	Test Readiness Review	3	12	Medium	6	24	Medium
	Production Readiness Review	3	12	Medium	6	24	Medium

TABLE N-11 – LAMINAR FLOW COATING/RIBLETS (AV-5)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
5	Develop Initial Prototypes	2	8	Medium	20	80	Medium
	Detailed Analysis (Modeling & Simulation)	2	8	Medium	10	40	Medium
	Critical Design Review	0.5	2	Medium	1	4	Medium
6	Fabricate/Assemble/Code to Product Specs	2	8	Medium	20	80	Medium
	Develop Simulators	2	8	Medium	20	80	Medium
	Develop Test Plans & Verification Options	1	4	Medium	2	8	Medium
7	Individual Test & Evaluation	1	4	Medium	10	40	Medium
	Integrated Test & Evaluation	1	4	Medium	10	40	Medium
	Test Readiness Review	1	4	Medium	2	8	Medium
	Production Readiness Review	1	4	Medium	2	8	Medium

TABLE N-12 – ADVANCED COMPOSITE MATERIALS (S-6)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
5	Develop Initial Prototypes	4	16	Medium	10	40	Medium
	Detailed Analysis (Modeling & Simulation)	3	12	Medium	5	20	Medium
	Critical Design Review	1	4	Medium	3	112	Medium
6	Fabricate/Assemble/Code to Product Specs	4	16	Medium	20	80	Medium
	Develop Simulators	4	16	Medium	20	80	Medium
	Develop Test Plans & Verification Options	3	1	Medium	5	20	Medium
7	Individual Test & Evaluation	6	24	Medium	10	40	Medium
	Integrated Test & Evaluation	6	24	Medium	10	40	Medium
	Test Readiness Review	6	24	Medium	3	12	Medium
	Production Readiness Review	6	24	Medium	3	12	Medium

TABLE N-13 – OUT-OF-AUTOCLAVE CURING (S-9)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
5	Develop Initial Prototypes	4	16	Medium	10	40	Medium
	Detailed Analysis (Modeling & Simulation)	3	12	Medium	5	20	Medium
	Critical Design Review	1	4	Medium	3	12	Medium
6	Fabricate/Assemble/Code to Product Specs	4	16	Medium	20	80	Medium
	Develop Simulators	4	16	Medium	20	80	Medium
	Develop Test Plans & Verification Options	3	12	Medium	5	20	Medium
7	Individual Test & Evaluation	3	12	Medium	5	20	Medium
	Integrated Test & Evaluation	3	12	Medium	5	20	Medium
	Test Readiness Review	3	12	Medium	2	8	Medium
	Production Readiness Review	3	12	Medium	2	8	Medium

TABLE N-14 – ADDITIVE MANUFACTURING (S-13)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
5	Develop Initial Prototypes	4	16	Medium	10	40	Medium
	Detailed Analysis (Modeling & Simulation)	3	12	Medium	5	20	Medium
	Critical Design Review	1	4	Medium	3	12	Medium
6	Fabricate/Assemble/Code to Product Specs	4	16	Medium	20	80	Medium
	Develop Simulators	4	16	Medium	20	80	Medium
	Develop Test Plans & Verification Options	3	12	Medium	5	20	Medium
7	Individual Test & Evaluation	6	24	Medium	10	40	Medium
	Integrated Test & Evaluation	6	24	Medium	10	40	Medium
	Test Readiness Review	6	24	Medium	3	12	Medium
	Production Readiness Review	6	24	Medium	3	12	Medium

TABLE N-15 – 3D PREFORMS (S-14)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
5	Develop Initial Prototypes	4	16	Medium	10	40	Medium
	Detailed Analysis (Modeling & Simulation)	3	12	Medium	5	20	Medium
	Critical Design Review	1	4	Medium	3	12	Medium
6	Fabricate/Assemble/Code to Product Specs	4	16	Medium	20	80	Medium
	Develop Simulators	4	16	Medium	20	80	Medium
	Develop Test Plans & Verification Options	3	12	Medium	5	20	Medium
7	Individual Test & Evaluation	3	12	Medium	5	20	Medium
	Integrated Test & Evaluation	3	12	Medium	5	20	Medium
	Test Readiness Review	3	12	Medium	2	8	Medium
	Production Readiness Review	3	12	Medium	2	8	Medium

TABLE N-16 – ADAPTIVE AND MORPHING MATERIALS (S-17)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
5	Develop Initial Prototypes	4	16	Medium	10	40	Medium
	Detailed Analysis (Modeling & Simulation)	3	12	Medium	5	20	Medium
	Critical Design Review	1	4	Medium	3	12	Medium
6	Fabricate/Assemble/Code to Product Specs	4	16	Medium	30	120	Medium
	Develop Simulators	4	16	Medium	30	120	Medium
	Develop Test Plans & Verification Options	3	12	Medium	10	40	Medium
7	Individual Test & Evaluation	6	24	Medium	20	80	Medium
	Integrated Test & Evaluation	6	24	Medium	20	80	Medium
	Test Readiness Review	6	24	Medium	6	24	Medium
	Production Readiness Review	6	24	Medium	6	24	Medium

TABLE N-17 – HIGH TEMPERATURE CERAMICS (S-20)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
6	Fabricate/Assemble/Code to Product Specs	10	40	Medium	20	80	Medium
	Develop Simulators	4	16	Medium	20	80	Medium
	Develop Test Plans & Verification Options	5	20	Medium	10	40	Medium
7	Individual Test & Evaluation	10	40	Medium	10	40	Medium
	Integrated Test & Evaluation	10	40	Medium	10	40	Medium
	Test Readiness Review	10	40	Medium	5	20	Medium
	Production Readiness Review	10	40	Medium	5	20	Medium

TABLE N-18 – INNOVATIVE LOAD SUPPRESSION (S-21)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
6	Fabricate/Assemble/Code to Product Specs	10	40	Medium	10	40	Medium
	Develop Simulators	20	80	Medium	10	40	Medium
	Develop Test Plans & Verification Options	5	20	Medium	5	20	Medium
7	Individual Test & Evaluation	10	40	Medium	5	20	Medium
	Integrated Test & Evaluation	10	40	Medium	5	20	Medium
	Test Readiness Review	10	40	Medium	5	20	Medium
	Production Readiness Review	10	40	Medium	5	20	Medium

TABLE N-19 – MULTI-FUNCTIONAL MATERIALS (S-22)

TRI Level	Activity/Milestone	Schedule (Months)			Manpower (FTEs)		
		Low	High	Confidence	Low	High	Confidence
5	Develop Initial Prototypes	4	16	Medium	10	40	Medium
	Detailed Analysis (Modeling & Simulation)	3	12	Medium	5	20	Medium
	Critical Design Review	1	4	Medium	3	12	Medium
6	Fabricate/Assemble/Code to Product Specs	4	16	Medium	30	120	Medium
	Develop Simulators	4	16	Medium	30	120	Medium
	Develop Test Plans & Verification Options	3	12	Medium	10	40	Medium
7	Individual Test & Evaluation	6	24	Medium	20	80	Medium
	Integrated Test & Evaluation	6	24	Medium	20	80	Medium
	Test Readiness Review	6	24	Medium	6	24	Medium
	Production Readiness Review	6	24	Medium	6	24	Medium

APPENDIX O—Cost Assessment Results

Total Ownership Cost (TOC)

The following tables show the TOC results for each aircraft configuration and deployment scenario (E = Evolutionary, M = Moderate, A = Aggressive). All results are displayed at a level no lower than a million dollars. Based on uncertainty analysis conducted for this study the 2024 EIS scenario results are determined to be accurate within +/- 15% and 2034 EIS scenario results at +/1 20%. All results have been normalized to be shown in a consistent economic base year (2013) regardless of when the costs will be incurred. This allows analysts to see the true cost delta between the scenarios and not have the data altered by inflationary impacts.

TABLE O-1 – SA TOC—DISCOUNTED AND UNDISCOUNTED MEAN RESULTS

	SA – 2024				SA – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Millions of USD								
Total ownership cost	**320,955**	**291,910**	**285,786**	**283,137**	**470,897**	**399,598**	**392,632**	**402,002**
Operator capital investment	120,026	166,258	185,776	199,672	145,624	223,531	242,810	283,465
Operator expense for 7 years	242,852	183,722	164,898	153,206	376,136	254,142	234,631	217,546
Fuel cost total for 7 years	203,838	151,512	134,138	122,229	323,035	212,416	192,474	174,189
Maintenance cost total for 7 years	39,014	32,210	30,760	30,978	53,101	41,725	42,157	43,357
Operator income after 17 years (residual value)	41,923	58,071	64,888	69,742	50,863	78,075	84,809	99,008
Average TOC per A/C for all A/C purchased	**80**	**73**	**71**	**70**	**86**	**73**	**72**	**74**
Average operator capital investment per A/C	30	41	46	59	27	41	44	52
Average operator expense per A/C	60	46	41	38	68	47	43	40
Average fuel cost per A/C	51	38	33	30	59	39	35	32
Average maintenance cost per A/C	10	8	8	8	10	8	8	8
Operator income (residual value)	10	14	16	17	9	14	16	18
Average TOC per A/C for A/C purchased in 1st yr	**77**	**70**	**69**	**68**	**82**	**70**	**69**	**71**
Average operator capital investment per A/C	30	41	46	50	27	41	44	52
Average operator expense per A/C	57	43	39	36	64	44	40	37
Average fuel cost per A/C	47	35	31	28	55	36	33	30
Average maintenance cost per A/C	10	8	8	8	10	8	8	8
Operator income (residual value)	10	14	16	17	9	14	16	18
DISCOUNTED (9%) —Mean Costs in BY2013 Millions of USD								
Total ownership cost	**82,213**	**81,384**	**82,336**	**83,369**	**49,415**	**46,825**	**47,136**	**49,962**
Operator capital investment	33,242	46,047	51,452	55,301	17,035	26,149	28,404	33,160
Operator expense for 7 years	51,653	39,053	35,036	32,531	33,755	22,787	21,025	19,479
Fuel cost total for 7 years	43,641	32,438	28,718	26,169	29,149	19,167	17,368	15,718
Maintenance cost total for 7 years	8,013	6,615	6,317	6,362	4,606	3,620	3,657	3,761
Operator income after 17 years (residual value)	2,683	3,716	4,153	4,463	1,375	2,110	2,292	2,676
Average TOC per A/C for all A/C purchased	**$20**	**$20**	**$20**	**$21**	**$9**	**$9**	**$9**	**$9**
Average operator capital investment per A/C	$8	$11	$13	$14	$3	$5	$5	$6
Average operator expense per A/C	$13	$10	$9	$8	$6	$4	$4	$4
Average fuel cost per A/C	$11	$8	$7	$7	$5	$4	$3	$3
Average maintenance cost per A/C	$2	$2	$2	$2	$1	$1	$1	$1
Operator income (residual value)	$1	$1	$1	$1	$0	$0	$0	$0
Average TOC per A/C for A/C purchased in 1st yr	**$29**	**$29**	**$29**	**$30**	**$13**	**$12**	**$12**	**$13**
Average operator capital investment per A/C	$12	$17	$19	$20	$5	$7	$8	$9
Average operator expense per A/C	$18	$14	$12	$11	$9	$6	$5	$5
Average fuel cost per A/C	$15	$11	$10	$9	$7	$5	$4	$4
Average maintenance cost per A/C	$3	$2	$2	$2	$1	$1	$1	$1
Operator income (residual value)	$1	$1	$2	$2	$0	$1	$1	$1

TABLE O-2 – STA TOC—DISCOUNTED AND UNDISCOUNTED MEAN RESULTS

	STA – 2024				STA – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Millions of USD								
Total ownership cost	**503,021**	**443,929**	**462,456**	**457,263**	**813,187**	**696,303**	**662,929**	**685,297**
Operator capital investment	$185,233	249,240	311,618	351,648	243,321	392,299	435,174	494,806
Operator expense for 7 years	$382,486	281,743	259,680	228,439	654,853	441,026	379,752	363,317
Fuel cost total for 7 years	$339,589	246,741	226,628	195,116	590,761	391,600	330,006	313,319
Maintenance cost total for 7 years	$42,897	35,002	33,052	33,322	64,092	49,426	49,747	49,998
Operator income after 17 years (residual value)	$64,698	87,055	108,842	122,824	84,987	137,022	151,997	172,826
Average TOC per A/C for all A/C purchased	**$353**	**312**	**325**	**321**	**382**	**327**	**312**	**322**
Average operator capital investment per A/C	$130	175	219	247	114	184	204	232
Average operator expense per A/C	$269	198	182	160	308	207	179	171
Average fuel cost per A/C	$239	173	159	137	278	184	155	147
Average maintenance cost per A/C	$30	25	23	23	30	23	23	24
Operator income (residual value)	$45	61	76	86	40	64	71	81
Average TOC per A/C for A/C purchased in 1st yr	**$337**	**300**	**314**	**312**	**361**	**313**	**300**	**311**
Average operator capital investment per A/C	$130	175	219	247	114	184	204	232
Average operator expense per A/C	$253	186	172	151	287	194	167	160
Average fuel cost per A/C	$223	162	149	128	257	170	144	136
Average maintenance cost per A/C	$30	25	23	23	30	23	23	24
Operator income (residual value)	$45	61	76	86	40	64	71	81
DISCOUNTED (9%) —Mean Costs in BY2013 Millions of USD								
Total ownership cost	**$126,765**	**122,613**	**133,717**	**137,200**	**84,433**	**81,246**	**80,338**	**85,235**
Operator capital investment	$50,963	68,574	85,736	96,750	28,278	45,592	50,574	57,504
Operator expense for 7 years	$80,916	59,575	54,903	48,262	58,437	39,335	33,845	32,372
Fuel cost total for 7 years	$72,164	52,434	48,159	41,463	52,914	35,075	29,558	28,064
Maintenance cost total for 7 years	$8,752	7,141	6,743	6,798	5,523	4,259	4,287	4,309
Operator income after 17 years (residual value)	$4,114	5,536	6,922	7,811	2,282	3,680	4,082	4,641
Average TOC per A/C for all A/C purchased	**$90**	**$86**	**$94**	**$96**	**$40**	**$38**	**$38**	**$40**
Average operator capital investment per A/C	$36	$48	$60	$68	$13	$21	$24	$27
Average operator expense per A/C	$57	$42	$39	$34	$27	$18	$16	$15
Average fuel cost per A/C	$51	$37	$34	$29	$25	$16	$14	$13
Average maintenance cost per A/C	$6	$5	$5	$5	$3	$2	$2	$2
Operator income (residual value)	$3	$4	$5	$5	$1	$2	$2	$2
Average TOC per A/C for A/C purchased in 1st yr	**$128**	**$123**	**$135**	**$139**	**$56**	**$55**	**$54**	**$58**
Average operator capital investment per A/C	$53	$71	$88	$100	$20	$31	$35	$40
Average operator expense per A/C	$79	$58	$54	$47	$38	$26	$22	$21
Average fuel cost per A/C	$70	$51	$47	$40	$34	$23	$19	$18
Average maintenance cost per A/C	$9	$7	$7	$7	$4	$3	$3	$3
Operator income (residual value)	$4	$6	$7	$8	$2	$3	$3	$3

TABLE O-3 – RJ TOC—DISCOUNTED AND UNDISCOUNTED MEAN RESULTS

	RJ – 2024				RJ – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Millions of USD								
Total ownership cost	**58,582**	**53,527**	**54,677**	**54,536**	**104,840**	**90,902**	**88,269**	**90,198**
Operator capital investment	22,992	31,987	36,724	40,267	33,073	49,835	53,733	62,510
Operator expense for 7 years	43,620	32,712	30,780	28,333	83,318	58,473	53,304	49,521
Fuel cost total for 7 years	36,448	26,342	24,439	21,958	71,272	47,814	42,604	38,677
Maintenance cost total for 7 years	7,173	6,370	6,342	6,375	12,046	10,659	10,700	10,844
Operator income after 17 years (residual value)	8,031	11,172	12,827	14,064	11,552	17,406	18,768	21,834

	RJ – 2024				RJ – 2034			
	Ref	E	M	A	Ref	E	M	A
Average TOC per A/C for all A/C purchased	**61**	**56**	**57**	**57**	**65**	**56**	**55**	**56**
Average operator capital investment per A/C	24	33	38	42	22	31	33	39
Average operator expense per A/C	46	34	32	30	53	36	33	31
Average fuel cost per A/C	38	28	26	23	44	30	27	24
Average maintenance cost per A/C	8	7	7	7	8	7	7	7
Operator income (residual value)	8	12	13	15	7	11	12	14
Average TOC per A/C for A/C purchased in 1st yr	**59**	**54**	**55**	**55**	**62**	**54**	**53**	**54**
Average operator capital investment per A/C	24	33	38	42	21	31	33	39
Average operator expense per A/C	43	32	30	28	48	34	31	29
Average fuel cost per A/C	36	26	24	21	41	27	24	22
Average maintenance cost per A/C	8	7	7	7	8	7	7	7
Operator income (residual value)	8	12	13	15	7	11	12	14
DISCOUNTED (9%) —Mean Costs in BY2013 Millions of USD								
Total ownership cost	**14,900**	**14,862**	**15,643**	**16,015**	**10,868**	**10,440**	**10,393**	**10,986**
Operator capital investment	6,271	8,724	10,016	10,983	3,811	5,743	6,192	7,203
Operator expense for 7 years	9,135	6,842	6,435	5,919	7,364	5,161	4,701	4,364
Fuel cost total for 7 years	7,685	5,554	5,153	4,630	6,335	4,250	3,787	3,438
Maintenance cost total for 7 years	1,451	1,288	1,283	1,289	1,029	911	914	927
Operator income after 17 years (residual value)	506	704	808	886	308	463	500	581
Average TOC per A/C for all A/C purchased	**$16**	**$15**	**$16**	**$17**	**$7**	**$6**	**$6**	**$7**
Average operator capital investment per A/C	$7	$9	$10	$11	$2	$4	$4	$4
Average operator expense per A/C	$10	$7	$7	$6	$5	$3	$3	$3
Average fuel cost per A/C	$8	$6	$5	$5	$4	$3	$2	$2
Average maintenance cost per A/C	$2	$1	$1	$1	$1	$1	$1	$1
Operator income (residual value)	$1	$1	$1	$1	$0	$0	$0	$0
Average TOC per A/C for A/C purchased in 1st yr	**$22**	**$22**	**$24**	**$24**	**$10**	**$9**	**$9**	**$10**
Average operator capital investment per A/C	$10	$13	$15	$17	$4	$5	$6	$7
Average operator expense per A/C	$13	$10	$9	$9	$6	$4	$4	$4
Average fuel cost per A/C	$11	$8	$8	$7	$5	$4	$3	$3
Average maintenance cost per A/C	$2	$2	$2	$2	$1	$1	$1	$1
Operator income (residual value)	$1	$1	$1	$1	$0	$0	$0	$1

AUP Summary

The following tables show the Average Unit Price results for each aircraft configuration and deployment scenario.

TABLE O-4 – SA AUP MEAN RESULTS

	SA – 2024				SA – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Millions of USD								
Total Manufacturer Investment (NONRECURRING)	$0	$6,639	$11,766	$15,209	$0	$10,939	$12,873	$21,360
Total Production Quantity	4,024	4,024	4,024	4,024	5,477	5,477	5,477	5,477
Amortized Development Cost – per Vehicle	**$0**	**$2**	**$3**	**$4**	**$0**	**$2**	**$2**	**$4**
Total Manufacturer Production (RECURRING)	$100,022	$131,910	$143,048	$151,184	$121,353	$175,337	$189,469	$214,860
Total Production Quantity	4,024	4,024	4,024	4,024	5,477	5,477	5,477	5,477
Average Unit Production Cost	**$25**	**$33**	**$36**	**$38**	**$22**	**$32**	**$35**	**$39**
Amortized Development Cost – per Vehicle	$0	$2	$3	$4	$0	$2	$2	$4
Average Unit Production Cost	$25	$33	$36	$38	$22	$32	$35	$39
Profit (20%)	$5.0	$7	$8	$8	$4	$7	$7	$9
Operator Capital Investment per A/C	**$30**	**$41**	**$46**	**$50**	**$28**	**$41**	**$44**	**$52**

	SA – 2024				SA – 2034			
	Ref	E	M	A	Ref	E	M	A
DISCOUNTED (9%) —Mean Costs in BY2013 Millions of USD								
Average Operator Capital Cost for ALL A/C purchased	$8	$11	$13	$14	$3	$5	$5	$6
Average Operator Capital Cost for FIRST A/C purchased	$12	$17	$19	$20	$5	$7	$8	$9

TABLE O-5 – STA AUP MEAN RESULTS

	STA – 2024				STA – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Millions of USD								
Total Manufacturer Investment (NONRECURRING)	$0	$15,714	$33,819	$44,791	$0	$32,335	$39,723	$47,274
Total Production Quantity	1,426	1,426	1,426	1,426	2,131	2,131	2,131	2,131
Amortized Development Cost – per Vehicle	**$0.0**	**$11**	**$24**	**$31**	**$0**	**$15**	**$19**	**$22**
Total Manufacturer Production (RECURRING)	$150,229	$182,488	$211,128	$230,644	$196,070	$277,379	$303,275	$342,448
Total Production Quantity	1,426	1,426	1,426	1,426	2,131	2,131	2,131	2,131
Average Unit Production Cost	**$105**	**$128**	**$148**	**$162**	**$92**	**$130**	**$142**	**$161**
Amortized Development Cost – per Vehicle	$0	$11	$24	$31	$0	$15	$19	$22
Average Unit Production Cost	$105	$128	$148	$162	$92	$130	$142	$161
Profit (20%)	$21	$28	$34	$39	$18	$29	$32	$37
Operator Capital Investment per A/C	**$126**	**$167**	**$206**	**$232**	**$110**	**$174**	**$193**	**$220**
DISCOUNTED (9%) —Mean Costs in BY2013 Millions of USD								
Average Operator Capital Cost for ALL A/C purchased	$36	$48	$60	$68	$13	$21	$24	$27
Average Operator Capital Cost for FIRST A/C purchased	$53	$71	$88	$100	$20	$32	$35	$40

TABLE O-6 – RJ AUP MEAN RESULTS

	RJ – 2024				RJ – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Millions of USD								
Total Manufacturer Investment (NONRECURRING)	$0	$2,872	$4,701	$6,540	$0	$4,230	$5,576	$8,338
Total Production Quantity	961	961	961	961	1,614	1,614	1,614	1,614
Amortized Development Cost – per Vehicle	**$0**	**$3**	**$5**	**$7**	**$0**	**$3**	**$4**	**$5**
Total Manufacturer Production (RECURRING)	19,160	$23,783	$25,902	$27,015	$27,561	$37,299	$39,201	$43,754
Total Production Quantity	961	961	961	961	1,614	1,614	1,614	1,614
Average Unit Production Cost	**$20**	**$25**	**$27**	**$28**	**$17**	**$23**	**$24**	**$27**
Amortized Development Cost – per Vehicle	$0	$3	$5	$7	$0	$3	$5	$5
Average Unit Production Cost	$20	$25	$27	$28	$17	$23	$24	$27
Profit (20%)	$4	$6	$6	$7	$3	$5	$6	$7
AUP – Operator Capital Cost per A/C	**$24**	**$33**	**$38**	**$42**	**$21**	**$31**	**$33**	**$39**
DISCOUNTED (9%) —Mean Costs in BY2013 Millions of USD								
Average Operator Capital Cost for ALL A/C purchased	$7	$9	$10	$11	$2	$4	$4	$5
Average Operator Capital Cost for FIRST A/C purchased	$10	$14	$16	$17	$4	$5	$6	$7

Total Nonrecurring Cost

The following tables show the Total Nonrecurring Cost (manufacturer investment) results for each aircraft configuration and deployment scenario. The detail show the cost for technology maturation for each candidate, the overall system development cost, and the amortized development cost that is added to the average unit production cost to support AUP calculations.

TABLE O-7 – TOTAL NR MEAN COST—STA (IN BILLIONS)

	SA – 2024				SA – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Billions of USD								
Total Manufacturer Investment	**$0**	**$6.639**	**$11.766**	**$15.209**	**$0**	**$10.939**	**$12.873**	**$21.360**
Technology Maturation	$0	$0.926	$2.034	$2.884	$-	$1.756	$2.553	$3.923
Aerodynamic Efficiency (Viscous)	$0		$0.077	$0.377	$-	$0.068	$0.334	$0.643
Aerodynamic Efficiency (Non-Viscous)	$0	$0.926	$1.421	$1.567	$-	$1.283	$1.418	$1.523
Structures	$0	$0	$0.517	$0.922	$-	$0.390	$0.785	$1.742
Aircraft Systems	$0	$0	$0.019	$0.019	$-	$0.015	$0.015	$0.015
System Development	**$0**	**$5.713**	**$9.732**	**$12.325**	**$0**	**$9.183**	**$10.320**	**$17.438**
Structure	$0	$1.095	$2.438	$3.264	$0	$2.370	$2.804	$3.957
Fuselage Group	$0	$0.383	$0.925	$1.178	$0	$0.881	$1.040	$1.253
Wing Group	$0	$0.587	$1.131	$1.589	$0	$1.110	$1.345	$2.168
Structure Box	$0	$0.522	$0.987	$1.403	$0	$0.959	$1.172	$1.931
Flaps	$0	$0.041	$0.078	$0.101	$0	$0.083	$0.093	$0.125
Slats	$0	$0.012	$0.032	$0.040	$0	$0.032	$0.038	$0.053
Spoilers	$0	$0.006	$0.014	$0.019	$0	$0.015	$0.018	$0.024
Ailerons	$0	$0.005	$0.009	$0.012	$0	$0.010	$0.011	$0.017
Winglets	$0	$0.001	$0.012	$0.015	$0	$0.011	$0.013	$0.017
Empennage	$0	$0.109	$0.298	$0.387	$0	$0.304	$0.330	$0.398
Stabilizer	$0	$0.067	$0.185	$0.240	$0	$0.188	$0.204	$0.231
Fin	$0	$0.042	$0.113	$0.147	$0	$0.116	$0.127	$0.167
Landing Gear	$0	$0.015	$0.083	$0.110	$0	$0.075	$0.089	$0.138
Propulsion	$0	$0.734	$0.874	$1.282	$0	$0.836	$1.108	$1.665
Engine	$0	$0.728	$0.869	$1.276	$0	$0.828	$1.099	$1.644
Core	$0	$0.579	$0.628	$0.952	$0	$0.564	$0.817	$1.320
Pylon	$0	$0.020	$0.038	$0.052	$0	$0.040	$0.046	$0.067
Nacelle	$0	$0.129	$0.202	$0.272	$0	$0.224	$0.236	$0.257
Fuel System	$0	$0.005	$0.006	$0.006	$0	$0.009	$0.009	$0.021
Systems	$0	$0.574	$0.841	$1.035	$0	$0.869	$0.979	$1.512
Auxiliary Power Unit	$0	$0.008	$0.009	$0.010	$0	$0.014	$0.014	$0.036
Surface Controls	$0	$0.199	$0.317	$0.369	$0	$0.312	$0.340	$0.415
Hydraulics	$0	$0.039	$0.041	$0.045	$0	$0.060	$0.061	$0.141
Electrical	$0	$0.103	$0.121	$0.154	$0	$0.120	$0.137	$0.176
Furnishings	$0	$0.067	$0.178	$0.241	$0	$0.156	$0.202	$0.358
Air Conditioning	$0	$0.009	$0.010	$0.011	$0	$0.015	$0.016	$0.041
Avionics	$0	$0.107	$0.123	$0.156	$0	$0.123	$0.139	$0.177
Misc Systems	$0	$0.042	$0.044	$0.049	$0	$0.069	$0.070	$0.167
Air Vehicle Integration	$0	$0.297	$0.370	$0.450	$0	$0.348	$0.370	$0.409
Software Development	$-	$1.109	$2.479	$2.736	$-	$2.339	$2.339	$6.206
SE/PM	$0	$0.418	$0.874	$1.281	$0	$0.819	$0.957	$1.469
Test	$0	$1.433	$1.781	$2.188	$0	$1.529	$1.684	$2.112
Support Investment	$0	$0.054	$0.075	$0.088	$0	$0.072	$0.079	$0.106
DISCOUNTED (9%)—Mean Costs in BY2013 Billions of USD								
Total Manufacturer Investment	**$0**	**$3.717**	**$6.819**	**$8.893**	**$0**	**$3.431**	**$4.329**	**$6.943**
Technology Maturation	$-	$0.718	$1.642	$2.326	$-	$1.365	$2.005	$2.982
System Development	$0	$2.998	$5.177	$6.567	$0	$2.066	$2.324	$3.961

	SA – 2024				SA – 2034			
	Ref	E	M	A	Ref	E	M	A
Aircraft	$0	$2.590	$4.704	$5.842	$0	$1.900	$2.087	$3.576
Engine	$0	$0.408	$0.473	$0.725	$0	$0.166	$0.237	$0.385
DISCOUNTED (9%) —Average Costs in Millions of USD								
Total Manufacturer Investment (Nonrecurring)	$0	$3,717	$6,819	$8,893	$0	$3,431	$4,329	$6,943
Total Production Quantity	4,024	4,024	4,024	4,024	5,477	5,477	5,477	5,477
Amortized Discounted Dev. Cost – per Vehicle	$0	$1	$2	$2	$0	$1	$1	$1

TABLE O-8 – TOTAL NR MEAN COST—STA (IN BILLIONS)

	STA – 2024				STA – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Billions of USD								
Total Manufacturer Investment	**$0**	**$15.714**	**$33.819**	**$44.791**	**$0**	**$32.335**	**$39.723**	**$47.274**
Technology Maturation	$-	$0.519	$1.995	$3.220	$-	$1.693	$2.813	$3.874
Aerodynamic Efficiency (Viscous)	$-	$-	$0.067	$0.713	$-	$0.059	$0.625	$0.625
Aerodynamic Efficiency (Non-Viscous)	$-	$0.519	$1.392	$1.567	$-	$1.229	$1.388	$1.492
Structures	$-	$-	$0.517	$0.922	$-	$0.390	$0.785	$1.742
Aircraft Systems	$-	$-	$0.019	$0.019	$-	$0.015	$0.015	$0.015
System Development	**$0**	**$15.196**	**$31.824**	**$41.572**	**$0**	**$30.642**	**$36.909**	**$43.400**
Structure	$0	$2.693	$6.892	$10.430	$0	$7.078	$9.735	$12.088
Fuselage Group	$0	$1.394	$3.438	$4.709	$0	$3.557	$4.421	$5.018
Wing Group	$0	$0.973	$2.413	$4.200	$0	$2.459	$3.895	$5.459
Structure Box	$0	$0.855	$2.125	$3.887	$0	$2.154	$3.591	$5.070
Flaps	$0	$0.067	$0.133	$0.171	$0	$0.144	$0.167	$0.212
Slats	$0	$0.027	$0.070	$0.102	$0	$0.076	$0.098	$0.125
Spoilers	$0	$0.007	$0.017	$0.023	$0	$0.019	$0.023	$0.029
Ailerons	$0	$0.006	$0.012	$0.016	$0	$0.013	$0.016	$0.022
Winglets	$0	$0.010	$0.057	$0.000	$0	$0.053	$0.000	$0.000
Empennage	$0	$0.255	$0.688	$0.999	$0	$0.738	$0.929	$0.977
Stabilizer	$0	$0.178	$0.484	$0.668	$0	$0.519	$0.618	$0.655
Fin	$0	$0.077	$0.204	$0.332	$0	$0.219	$0.311	$0.321
Landing Gear	$0	$0.072	$0.354	$0.522	$0	$0.323	$0.491	$0.635
Propulsion	$0	$2.247	$2.991	$4.508	$0	$2.894	$4.066	$4.721
Engine	$0	$2.240	$2.983	$4.499	$0	$2.882	$4.054	$4.693
Core	$0	$1.829	$2.334	$3.680	$0	$2.180	$3.301	$3.848
Pylon	$0	$0.057	$0.107	$0.134	$0	$0.110	$0.126	$0.179
Nacelle	$0	$0.354	$0.542	$0.685	$0	$0.592	$0.627	$0.665
Fuel System	$0	$0.008	$0.008	$0.009	$0	$0.012	$0.013	$0.028
Systems	$0	$0.967	$1.749	$2.225	$0	$1.822	$2.195	$3.407
Auxiliary Power Unit	$0	$0.013	$0.014	$0.016	$0	$0.022	$0.023	$0.056
Surface Controls	$0	$0.231	$0.474	$0.588	$0	$0.480	$0.563	$0.668
Hydraulics	$0	$0.100	$0.106	$0.116	$0	$0.150	$0.156	$0.346
Electrical	$0	$0.168	$0.200	$0.264	$0	$0.201	$0.246	$0.318
Furnishings	$0	$0.080	$0.527	$0.718	$0	$0.467	$0.627	$1.057
Air Conditioning	$0	$0.018	$0.020	$0.022	$0	$0.031	$0.033	$0.079
Avionics	$0	$0.254	$0.299	$0.379	$0	$0.304	$0.370	$0.472
Misc Systems	$0	$0.104	$0.110	$0.121	$0	$0.169	$0.175	$0.411
Air Vehicle Integration	$0	$1.160	$1.418	$1.829	$0	$1.324	$1.571	$1.689
Software Development	$-	$4.487	$13.154	$14.519	$-	$12.409	$12.906	$13.402
SE/PM	$0	$0.918	$2.248	$3.663	$0	$2.198	$3.066	$4.076
Test	$0	$2.575	$3.144	$4.116	$0	$2.697	$3.116	$3.686
Support Investment	$0	$0.148	$0.228	$0.282	$0	$0.220	$0.254	$0.329
DISCOUNTED (9%) —Mean Costs in BY2013 Billions of USD								
Total Manufacturer Investment	**$-**	**$8.442**	**$18.688**	**$24.928**	**$0.000**	**$8.270**	**$10.575**	**$12.792**
Technology Maturation	$-	$0.426	$1.609	$2.604	$-	$1.314	$2.191	$2.942

	STA – 2024				STA – 2034			
	Ref	E	M	A	Ref	E	M	A
System Development	$-	$8.016	$17.078	$22.324	$0.000	$6.956	$8.385	$9.850
Aircraft	$-	$6.736	$15.408	$19.710	$0.000	$6.343	$7.473	$8.719
Engine	$-	$1.280	$1.670	$2.615	$0.000	$0.613	$0.912	$1.132
DISCOUNTED (9%) —Average Costs in Millions of USD								
Total Manufacturer Investment (Nonrecurring)	—	$8,442	$18,688	$24,928	$0	$8,270	$10,575	$12,792
Total Production Quantity	1,426	1,426	1,426	1,426	2,131	2,131	2,131	2,131
Amortized Discounted Dev. Cost – per Vehicle	—	$6	$13	$17	$0	$4	$5	$6

TABLE O-9 – TOTAL NR MEAN COST—RJ (IN BILLIONS)

	RJ – 2024				RJ – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Billions of USD								
Total Manufacturer Investment	**$0**	**$2.872**	**$4.701**	**$6.540**	**$0**	**$4.230**	**$5.576**	**$8.338**
Technology Maturation	$-	$0.391	$1.159	$1.943	$-	$0.952	$1.683	$2.388
Aerodynamic Efficiency (Viscous)	$-	$-	$-	$0.290	$-	$-	$0.257	$0.288
Aerodynamic Efficiency (Non-Viscous)	$-	$0.391	$0.623	$0.713	$-	$0.546	$0.625	$0.673
Structures	$-	$-	$0.517	$0.922	$-	$0.390	$0.785	$1.412
Aircraft Systems	$-	$-	$0.019	$0.019	$-	$0.015	$0.015	$0.015
System Development	**$0**	**$2.481**	**$3.542**	**$4.597**	**$0**	**$3.278**	**$3.893**	**$5.949**
Structure	$0	$0.392	$0.779	$1.039	$0	$0.732	$0.925	$1.165
Fuselage Group	$0	$0.139	$0.296	$0.376	$0	$0.281	$0.337	$0.414
Wing Group	$0	$0.204	$0.374	$0.524	$0	$0.350	$0.463	$0.599
Structure Box	$0	$0.183	$0.322	$0.456	$0	$0.299	$0.403	$0.518
Flaps	$0	$0.011	$0.025	$0.033	$0	$0.025	$0.030	$0.038
Slats	$0	$0.005	$0.012	$0.015	$0	$0.011	$0.013	$0.019
Spoilers	$0	$0.002	$0.003	$0.005	$0	$0.003	$0.004	$0.006
Ailerons	$0	$0.001	$0.003	$0.004	$0	$0.003	$0.003	$0.005
Winglets	$0	$0.001	$0.009	$0.012	$0	$0.009	$0.010	$0.012
Empennage	$0	$0.043	$0.085	$0.106	$0	$0.079	$0.094	$0.111
Stabilizer	$0	$0.026	$0.051	$0.064	$0	$0.048	$0.057	$0.064
Fin	$0	$0.017	$0.034	$0.042	$0	$0.031	$0.037	$0.047
Landing Gear	$0	$0.006	$0.025	$0.032	$0	$0.022	$0.030	$0.041
Propulsion	$0	$0.454	$0.562	$0.785	$0	$0.530	$0.668	$1.063
Engine	$0	$0.451	$0.560	$0.782	$0	$0.526	$0.664	$1.054
Core	$0	$0.391	$0.467	$0.659	$0	$0.425	$0.556	$0.934
Pylon	$0	$0.010	$0.016	$0.022	$0	$0.016	$0.019	$0.025
Nacelle	$0	$0.050	$0.076	$0.101	$0	$0.085	$0.090	$0.095
Fuel System	$0	$0.003	$0.003	$0.003	$0	$0.004	$0.004	$0.009
Systems	$0	$0.179	$0.249	$0.313	$0	$0.260	$0.293	$0.460
Auxiliary Power Unit	$0	$0.003	$0.004	$0.004	$0	$0.005	$0.005	$0.013
Surface Controls	$0	$0.036	$0.059	$0.077	$0	$0.060	$0.071	$0.086
Hydraulics	$0	$0.020	$0.021	$0.024	$0	$0.028	$0.028	$0.061
Electrical	$0	$0.039	$0.045	$0.056	$0	$0.044	$0.049	$0.063
Furnishings	$0	$0.025	$0.058	$0.077	$0	$0.051	$0.063	$0.109
Air Conditioning	$0	$0.003	$0.004	$0.004	$0	$0.005	$0.005	$0.013
Avionics	$0	$0.036	$0.041	$0.052	$0	$0.041	$0.046	$0.057
Misc Systems	$0	$0.016	$0.017	$0.019	$0	$0.025	$0.025	$0.057
Air Vehicle Integration	$0	$0.091	$0.112	$0.133	$0	$0.102	$0.109	$0.114
Software Development	$-	$0.255	$0.435	$0.480	$-	$0.410	$0.500	$1.409
SE/PM	$0	$0.120	$0.243	$0.362	$0	$0.224	$0.278	$0.399
Test	$0	$0.960	$1.121	$1.437	$0	$0.982	$1.078	$1.288
Support Investment	$0	$0.031	$0.041	$0.047	$0	$0.038	$0.041	$0.052

	RJ – 2024				RJ – 2034			
	Ref	E	M	A	Ref	E	M	A
DISCOUNTED (9%)—Mean Costs in BY2013 Billions of USD								
Total Manufacturer Investment	**$0**	**$1.602**	**$2.807**	**$3.998**	**$0**	**$1.480**	**$2.212**	**$3.192**
Technology Maturation	$-	$0.323	$0.961	$1.596	$-	$0.757	$1.350	$1.860
System Development	$0	$1.279	$1.846	$2.403	$0	$0.723	$0.862	$1.331
Aircraft	$0	$1.003	$1.492	$1.893	$0	$0.597	$0.700	$1.058
Engine	$0	$0.277	$0.354	$0.510	$0	$0.125	$0.162	$0.273
DISCOUNTED (9%)—Average Costs in Millions of USD								
Total Manufacturer Investment (Nonrecurring)	$0	$1,602	$2,807	$3,998	$0	$1,480	$2,212	$3,192
Total Production Quantity	961	961	961	961	1,614	1,614	1,614	1,614
Amortized Discounted Dev. Cost – per Vehicle	$0	$2	$3	$4	$0	$1	$1	$2

Total Recurring Production Cost

The following tables show the Total Recurring Cost (manufacturer investment) results for each aircraft configuration and deployment scenario. The detail shows the cost by WBS for producing all the aircraft over a ten-year purchase period. This cost is the basis for the average unit production cost that supports AUP calculations.

TABLE O-10 – TOTAL RECURRING PROD MEAN COST SA

	SA – 2024				SA – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Billions of USD								
Total Recurring Production Cost	**$100.022**	**$131.910**	**$143.048**	**$151.184**	**$121.353**	**$175.337**	**$189.469**	**$214.860**
Total Aircraft	$82.390	$106.314	$116.301	$122.615	$100.324	$142.613	$154.877	$178.823
Structure	$16.360	$27.395	$35.120	$36.431	$19.187	$43.212	$45.645	$51.365
Fuselage Group	$5.072	$8.292	$10.669	$11.005	$5.949	$13.008	$13.749	$14.198
Wing Group	$7.331	$14.423	$18.128	$18.927	$8.598	$22.416	$23.676	$28.306
Structure Box	$5.783	$12.332	$15.325	$15.956	$6.782	$18.917	$19.923	$23.851
Flaps	$0.803	$1.092	$1.384	$1.479	$0.942	$1.755	$1.828	$2.170
Slats	$0.355	$0.478	$0.693	$0.717	$0.416	$0.840	$0.934	$1.107
Spoilers	$0.181	$0.223	$0.309	$0.336	$0.212	$0.392	$0.433	$0.505
Ailerons	$0.079	$0.126	$0.164	$0.175	$0.093	$0.207	$0.226	$0.309
Winglets	$0.130	$0.171	$0.254	$0.263	$0.152	$0.304	$0.333	$0.364
Empennage	$2.329	$2.976	$3.823	$3.862	$2.731	$4.739	$4.850	$5.053
Stabilizer	$1.511	$1.836	$2.379	$2.403	$1.772	$2.931	$2.999	$2.941
Fin	$0.817	$1.139	$1.444	$1.460	$0.959	$1.808	$1.851	$2.112
Landing Gear	$1.628	$1.705	$2.500	$2.637	$1.909	$3.049	$3.371	$3.808
Propulsion	$37.326	$44.483	$43.799	$47.706	$46.835	$54.349	$60.812	$71.898
Engine	$37.085	$44.204	$43.509	$47.417	$46.552	$53.976	$60.423	$71.386
Core	$31.834	$38.879	$37.601	$41.230	$40.394	$46.494	$52.917	$64.170
Pylon	$1.626	$1.455	$1.613	$1.684	$1.907	$1.960	$2.069	$2.237
Nacelle	$3.625	$3.870	$4.295	$4.503	$4.251	$5.523	$5.436	$4.979
Fuel System	$0.241	$0.278	$0.290	$0.289	$0.283	$0.373	$0.389	$0.512
Systems	$28.704	$34.435	$37.383	$38.477	$34.302	$45.052	$48.420	$55.560
Auxiliary Power Unit	$0.441	$0.516	$0.543	$0.545	$0.517	$0.698	$0.728	$0.978
Surface Controls	$1.854	$3.469	$4.251	$4.559	$2.174	$5.201	$5.714	$6.225
Hydraulics	$4.946	$5.522	$5.621	$5.562	$5.801	$7.236	$7.422	$9.537
Electrical	$2.950	$4.090	$4.302	$4.438	$3.459	$5.060	$5.469	$5.775
Furnishings	$8.843	$9.755	$11.413	$12.075	$10.371	$12.669	$14.323	$16.947
Air Conditioning	$0.481	$0.562	$0.591	$0.593	$0.564	$0.758	$0.791	$1.062
Avionics	$6.647	$7.756	$7.898	$7.992	$8.434	$9.863	$10.351	$10.493
Misc Systems	$2.542	$2.766	$2.763	$2.713	$2.981	$3.566	$3.622	$4.542

	SA – 2024				SA – 2034			
	Ref	E	M	A	Ref	E	M	A
Air Vehicle Integration	$10.402	$16.430	$16.808	$17.942	$12.199	$20.608	$21.298	$20.718
SE/PM	$7.230	$9.167	$9.939	$10.627	$8.830	$12.115	$13.294	$15.320
DISCOUNTED (9%) —Mean Costs in BY2013 Billions of USD								
Total Production no Profit with 9% Discounting	**$27.950**	**$38.311**	**$41.799**	**$44.228**	**$14.303**	**$21.680**	**$23.442**	**$26.686**
Buy Quantity	4,024	4,024	4,024	4,024	5,477	5,477	5,477	5,477
Buy Quantity—Year 1	349	349	349	349	475	475	475	475
Buy Quantity—Year 2	360	360	360	360	490	490	490	490
Buy Quantity—Year 3	371	371	371	371	505	505	505	505
Buy Quantity—Year 4	383	383	383	383	521	521	521	521
Buy Quantity—Year 5	395	395	395	395	537	537	537	537
Buy Quantity—Year 6	407	407	407	407	554	554	554	554
Buy Quantity—Year 7	420	420	420	420	571	571	571	571
Buy Quantity—Year 8	433	433	433	433	589	589	589	589
Buy Quantity—Year 9	446	446	446	446	608	608	608	608
Buy Quantity—Year 10	460	460	460	460	627	627	627	627

TABLE O-11 – TOTAL RECURRING PROD MEAN COST STA

	STA – 2024				STA – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Billions of USD								
Total Recurring Production Cost	**$150.229**	**$182.488**	**$211.128**	**$230.644**	**$196.070**	**$277.379**	**$303.275**	**$342.448**
Total Aircraft	$115.156	$135.550	$161.045	$174.696	$151.193	$212.719	$231.522	$266.677
Structure	$30.948	$40.423	$58.577	$66.407	$39.119	$76.772	$88.218	$98.672
Fuselage Group	$14.401	$18.767	$27.736	$29.677	$18.207	$36.571	$39.510	$42.162
Wing Group	$8.789	$13.688	$19.547	$24.248	$11.107	$25.460	$32.115	$38.642
Structure Box	$7.475	$11.687	$16.754	$21.957	$9.447	$21.800	$29.061	$34.954
Flaps	$0.708	$0.842	$1.162	$1.172	$0.895	$1.541	$1.560	$1.907
Slats	$0.432	$0.497	$0.756	$0.809	$0.545	$0.998	$1.080	$1.271
Spoilers	$0.117	$0.134	$0.193	$0.195	$0.148	$0.258	$0.262	$0.310
Ailerons	$0.057	$0.077	$0.105	$0.113	$0.072	$0.139	$0.151	$0.200
Winglets	$0.000	$0.451	$0.578	$0.000	$0.000	$0.724	$0.000	$0.000
Empennage	$3.521	$3.720	$5.106	$5.508	$4.450	$6.697	$7.227	$7.443
Stabilizer	$2.514	$2.604	$3.590	$3.681	$3.178	$4.709	$4.812	$4.998
Fin	$1.007	$1.116	$1.516	$1.827	$1.273	$1.988	$2.416	$2.444
Landing Gear	$4.236	$4.248	$6.187	$6.975	$5.354	$8.044	$9.366	$10.425
Propulsion	$50.426	$57.556	$59.936	$63.633	$68.632	$81.354	$84.659	$98.885
Engine	$50.254	$57.367	$59.740	$63.440	$68.415	$81.086	$84.385	$98.529
Core	$42.050	$49.233	$50.812	$54.493	$58.047	$69.205	$73.020	$86.949
Pylon	$2.538	$2.255	$2.466	$2.454	$3.209	$3.163	$3.185	$3.560
Nacelle	$5.666	$5.879	$6.462	$6.492	$7.160	$8.718	$8.180	$8.020
Fuel System	$0.172	$0.189	$0.196	$0.193	$0.217	$0.268	$0.275	$0.356
Systems	$33.782	$37.571	$42.531	$44.657	$43.442	$54.594	$58.644	$69.120
Auxiliary Power Unit	$0.351	$0.406	$0.427	$0.428	$0.444	$0.585	$0.608	$0.801
Surface Controls	$1.424	$2.342	$3.066	$3.337	$1.800	$4.013	$4.368	$4.800
Hydraulics	$5.893	$6.260	$6.339	$6.225	$7.451	$8.697	$8.803	$11.350
Electrical	$2.440	$3.429	$3.701	$3.949	$3.085	$4.654	$5.076	$5.645
Furnishings	$13.492	$13.595	$17.076	$18.501	$17.054	$20.459	$22.933	$27.331
Air Conditioning	$0.512	$0.592	$0.622	$0.624	$0.647	$0.853	$0.887	$1.170
Avionics	$6.340	$7.460	$7.784	$8.146	$8.751	$10.512	$11.103	$11.773
Misc Systems	$3.331	$3.488	$3.517	$3.447	$4.211	$4.820	$4.866	$6.250
Air Vehicle Integration	$24.241	$34.255	$35.461	$39.709	$30.644	$45.536	$50.520	$51.360
SE/PM	$10.832	$12.684	$14.623	$16.239	$14.233	$19.124	$21.233	$24.410

	STA – 2024				STA – 2034			
	Ref	E	M	A	Ref	E	M	A
DISCOUNTED (9%) —Mean Costs in BY2013 Billions of USD								
Total Production no Profit with 9% Discounting	**$41.763**	**$61.080**	**$80.011**	**$92.035**	**$22.992**	**$34.105**	**$37.346**	**$42.314**
Buy Quantity	1,426	1,426	1,426	1,426	2,131	2,131	2,131	2,131
Buy Quantity—Year 1	118	118	118	118	177	177	177	177
Buy Quantity—Year 2	123	123	123	123	184	184	184	184
Buy Quantity—Year 3	128	128	128	128	191	191	191	191
Buy Quantity—Year 4	133	133	133	133	199	199	199	199
Buy Quantity—Year 5	139	139	139	139	207	207	207	207
Buy Quantity—Year 6	145	145	145	145	216	216	216	216
Buy Quantity—Year 7	150	150	150	150	225	225	225	225
Buy Quantity—Year 8	156	156	156	156	234	234	234	234
Buy Quantity—Year 9	163	163	163	163	243	243	243	243
Buy Quantity—Year 10	170	170	170	170	254	254	254	254

TABLE O-12 – TOTAL RECURRING PROD MEAN COST RJ

	RJ – 2024				RJ – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Billions of USD								
Total Recurring Production Cost	**$19.160**	**$23.783**	**$25.902**	**$27.015**	**$27.561**	**$37.299**	**$39.201**	**$43.754**
Total Aircraft	$16.642	$20.495	$22.448	$23.396	$24.003	$32.406	$34.093	$38.472
Structure	$3.311	$5.780	$6.767	$7.076	$4.517	$9.473	$10.280	$10.572
Fuselage Group	$0.991	$1.658	$1.963	$2.042	$1.351	$2.799	$2.994	$3.169
Wing Group	$1.499	$3.179	$3.699	$3.886	$2.044	$5.137	$5.610	$5.601
Structure Box	$1.114	$2.702	$3.091	$3.234	$1.520	$4.277	$4.673	$4.522
Flaps	$0.215	$0.224	$0.281	$0.303	$0.293	$0.408	$0.438	$0.489
Slats	$0.073	$0.110	$0.139	$0.148	$0.099	$0.192	$0.212	$0.266
Spoilers	$0.031	$0.033	$0.042	$0.046	$0.042	$0.060	$0.066	$0.082
Ailerons	$0.023	$0.028	$0.035	$0.039	$0.031	$0.050	$0.056	$0.072
Winglets	$0.043	$0.083	$0.111	$0.116	$0.059	$0.151	$0.166	$0.170
Empennage	$0.532	$0.634	$0.704	$0.724	$0.726	$0.973	$1.041	$1.118
Stabilizer	$0.350	$0.380	$0.426	$0.437	$0.477	$0.590	$0.629	$0.647
Fin	$0.183	$0.254	$0.279	$0.287	$0.249	$0.383	$0.412	$0.470
Landing Gear	$0.290	$0.309	$0.400	$0.425	$0.395	$0.564	$0.634	$0.685
Propulsion	$8.362	$9.140	$9.736	$10.206	$12.562	$14.575	$14.957	$18.034
Engine	$8.300	$9.074	$9.669	$10.139	$12.478	$14.477	$14.855	$17.906
Core	$7.257	$7.930	$8.431	$8.854	$11.055	$12.656	$13.012	$16.276
Pylon	$0.368	$0.359	$0.388	$0.400	$0.502	$0.545	$0.576	$0.503
Nacelle	$0.674	$0.785	$0.850	$0.884	$0.920	$1.276	$1.267	$1.127
Fuel System	$0.062	$0.066	$0.067	$0.067	$0.084	$0.098	$0.102	$0.128
Systems	$4.969	$5.576	$5.945	$6.114	$6.925	$8.358	$8.856	$9.865
Auxiliary Power Unit	$0.091	$0.102	$0.107	$0.107	$0.124	$0.157	$0.163	$0.207
Surface Controls	$0.452	$0.589	$0.692	$0.735	$0.617	$0.965	$1.052	$1.114
Hydraulics	$1.023	$1.101	$1.120	$1.103	$1.395	$1.637	$1.669	$2.026
Electrical	$0.574	$0.718	$0.742	$0.766	$0.783	$1.016	$1.078	$1.098
Furnishings	$1.358	$1.464	$1.667	$1.777	$1.853	$2.186	$2.421	$2.786
Air Conditioning	$0.085	$0.096	$0.100	$0.101	$0.116	$0.147	$0.152	$0.194
Avionics	$0.920	$1.016	$1.025	$1.046	$1.400	$1.536	$1.599	$1.587
Misc Systems	$0.466	$0.490	$0.490	$0.478	$0.636	$0.715	$0.722	$0.854
Air Vehicle Integration	$1.306	$1.903	$1.927	$2.003	$1.781	$2.683	$2.765	$2.564
SE/PM	$1.212	$1.385	$1.527	$1.617	$1.777	$2.211	$2.344	$2.719
DISCOUNTED (9%) —Mean Costs in BY2013 Billions of USD								
Total Production no Profit with 9% Discounting	**$5.289**	**$6.778**	**$7.420**	**$7.747**	**$3.209**	**$4.523**	**$4.761**	**$5.327**
Buy Quantity	961	961	961	961	1,614	1,614	1,614	1,614
Buy Quantity—Year 1	75	75	75	75	126	126	126	126

	RJ – 2024				RJ – 2034			
	Ref	E	M	A	Ref	E	M	A
Buy Quantity—Year 2	79	79	79	79	133	133	133	133
Buy Quantity—Year 3	83	83	83	83	140	140	140	140
Buy Quantity—Year 4	88	88	88	88	148	148	148	148
Buy Quantity—Year 5	93	93	93	93	156	156	156	156
Buy Quantity—Year 6	98	98	98	98	164	164	164	164
Buy Quantity—Year 7	103	103	103	103	172	172	172	172
Buy Quantity—Year 8	108	108	108	108	182	182	182	182
Buy Quantity—Year 9	114	114	114	114	191	191	191	191
Buy Quantity—Year 10	120	120	120	120	202	202	202	202

Average Unit Production Cost

TABLE O-13 – SA AVERAGE UNIT PRODUCTION MEAN COST

	SA – 2024				SA – 2034			
	Ref	E	M	A	Ref	E	M	A
DISCOUNTED (9%) —Average Costs in Millions of USD								
AUP Cost	**$7**	**$10**	**$10**	**$11**	**$3**	**$4**	**$4**	**$5**
Aircraft Discounted	$5	$8	$8	$8	$2	$3	$3	$3
Engine Discounted	$2	$3	$3	$3	$1	$1	$1	$1
AUP Cost with 20% Profit	**$8**	**$11**	**$12**	**$13**	**$3**	**$5**	**$5**	**$6**
AUP Price – Aircraft Discounted with 20% Profit	$6	$8	$9	$10	$2	$4	$4	$4
AUP Price – Engine Discounted with 20% Profit	$3	$3	$3	$4	$1	$1	$1	$2

TABLE O-14 – STA AVERAGE UNIT PRODUCTION MEAN COST

	STA – 2024				S%A – 2034			
	Ref	E	M	A	Ref	E	M	A
DISCOUNTED (9%)—Average Costs in Millions of USD								
AUP Cost	**$30**	**$38**	**$45**	**$49**	**$11**	**$17**	**$18**	**$21**
Aircraft Discounted	$22	$28	$34	$38	$8	$13	$14	$16
Engine Discounted	$8	$1	$10	$11	$3	$4	$4	$5
AUP Cost with 20% Profit	**$36**	**$46**	**$54**	**$59**	**$13**	**$20**	**$22**	**$25**
AUP Price – Aircraft Discounted with 20% Profit	$26	$34	$41	$45	$10	$15	$17	$19
AUP Price – Engine Discounted with 20% Profit	$10	$12	$12	$13	$4	$5	$5	$6

TABLE O-15 – RJ AVERAGE UNIT PRODUCTION MEAN COST

	RJ – 2024				RJ – 2034			
	Ref	E	M	A	Ref	E	M	A
DISCOUNTED (9%) —Average Costs in Millions of USD								
AUP Cost	**$6**	**$7**	**$8**	**$8**	**$2**	**$3**	**$3**	**$3**
Aircraft Discounted	$3	$5	$5	$5	$1	$2	$2	$2
Engine Discounted	$2	$2	$2	$3	$1	$1	$1	$1
AUP Cost with 20% Profit	**$7**	**$8**	**$9**	**$10**	**$2**	**$3**	**$4**	**$4**
AUP Price – Aircraft Discounted with 20% Profit	$4	$6	$6	$7	$1	$2	$2	$3
AUP Price – Engine Discounted with 20% Profit	$2	$3	$3	$3	$1	$1	$1	$1

Total Operational Cost (Fuel & Maintenance)

The following tables show the Total Nonrecurring Cost (manufacturer investment) results for each aircraft configuration and deployment scenario. The detail show the cost for technology maturation for each candidate, the overall system development cost, and the amortized development cost that is added to the average unit production cost to support AUP calculations.

TABLE O-16 – SA TOTAL OPERATIONAL MEAN COST (FUEL & MAINT)

	SA – 2024				SA – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Billions of USD								
Total Operational Expense	**$242.852**	**$183.722**	**$164.898**	**$153.206**	**$376.136**	**$254.142**	**$234.631**	**$217.546**
Fuel Cost	$203.838	$151.512	$134.138	$122.229	$323.035	$212.416	$192.474	$174.189
Total Fuel Costs for Purchase – Year 1	$16.880	$12.547	$11.108	$10.122	$26.749	$17.589	$15.938	$14.424
Total Fuel Costs for Purchase – Year 2	$17.581	$13.068	$11.569	$10.542	$27.861	$18.321	$16.601	$15.023
Total Fuel Costs for Purchase – Year 3	$18.293	$13.597	$12.038	$10.969	$28.993	$19.064	$17.275	$15.634
Total Fuel Costs for Purchase – Year 4	$19.068	$14.173	$12.548	$11.434	$30.201	$19.859	$17.995	$16.285
Total Fuel Costs for Purchase – Year 5	$19.857	$14.759	$13.067	$11.907	$31.431	$20.668	$18.727	$16.948
Total Fuel Costs for Purchase – Year 6	$20.658	$15.355	$13.594	$12.387	$32.740	$21.529	$19.508	$17.654
Total Fuel Costs for Purchase – Year 7	$21.525	$15.999	$14.165	$12.907	$34.072	$22.405	$20.301	$18.373
Total Fuel Costs for Purchase – Year 8	$22.406	$16.655	$14.745	$13.436	$35.487	$23.335	$21.144	$19.136
Total Fuel Costs for Purchase – Year 9	$23.303	$17.321	$15.335	$13.973	$36.987	$24.322	$22.038	$19.945
Total Fuel Costs for Purchase – Year 10	$24.268	$18.038	$15.969	$14.552	$38.513	$25.325	$22.947	$20.767
Maintenance Cost – Rampup	$39.014	$32.210	$30.760	$30.978	$53.101	$41.725	$42.157	$43.357
Total Maint Costs for Purchase – Year 1	$3.384	$2.794	$2.668	$2.687	$4.605	$3.619	$3.656	$3.760
Total Maint Costs for Purchase – Year 2	$3.490	$2.882	$2.752	$2.771	$4.751	$3.733	$3.772	$3.879
Total Maint Costs for Purchase – Year 3	$3.597	$2.970	$2.836	$2.856	$4.896	$3.847	$3.887	$3.998
Total Maint Costs for Purchase – Year 4	$3.713	$3.066	$2.928	$2.948	$5.051	$3.969	$4.010	$4.124
Total Maint Costs for Purchase – Year 5	$3.830	$3.162	$3.019	$3.041	$5.206	$4.091	$4.133	$4.251
Total Maint Costs for Purchase – Year 6	$3.946	$3.258	$3.111	$3.133	$5.371	$4.221	$4.264	$4.386
Total Maint Costs for Purchase – Year 7	$4.072	$3.362	$3.211	$3.233	$5.536	$4.350	$4.395	$4.520
Total Maint Costs for Purchase – Year 8	$4.198	$3.466	$3.310	$3.333	$5.711	$4.487	$4.534	$4.663
Total Maint Costs for Purchase – Year 9	$4.324	$3.570	$3.409	$3.433	$5.895	$4.632	$4.680	$4.813
Total Maint Costs for Purchase – Year 10	$4.460	$3.682	$3.516	$3.541	$6.079	$4.777	$4.826	$4.963
DISCOUNTED (9%) —Mean Costs in BY2013 Billions of USD								
Total Operational Expense	**$51.653**	**$39.053**	**$35.036**	**$32.531**	**$33.755**	**$22.787**	**$21.025**	**$19.479**
Fuel Cost	$43.641	$32.438	$28.718	$26.169	$29.149	$19.167	$17.368	$15.718
Total Fuel Costs for Purchase – Year 1	$5.316	$3.951	$3.498	$3.187	$3.550	$2.335	$2.115	$1.915
Total Fuel Costs for Purchase – Year 2	$5.079	$3.775	$3.342	$3.046	$3.393	$2.231	$2.022	$1.829
Total Fuel Costs for Purchase – Year 3	$4.849	$3.604	$3.191	$2.907	$3.239	$2.130	$1.930	$1.747
Total Fuel Costs for Purchase – Year 4	$4.637	$3.447	$3.051	$2.780	$3.095	$2.035	$1.844	$1.669
Total Fuel Costs for Purchase – Year 5	$4.430	$3.293	$2.915	$2.656	$2.956	$1.943	$1.761	$1.594
Total Fuel Costs for Purchase – Year 6	$4.228	$3.143	$2.782	$2.535	$2.824	$1.857	$1.683	$1.523
Total Fuel Costs for Purchase – Year 7	$4.042	$3.004	$2.660	$2.424	$2.697	$1.773	$1.607	$1.454
Total Fuel Costs for Purchase – Year 8	$3.860	$2.869	$2.540	$2.314	$2.577	$1.694	$1.535	$1.389
Total Fuel Costs for Purchase – Year 9	$3.683	$2.737	$2.424	$2.208	$2.464	$1.620	$1.468	$1.329
Total Fuel Costs for Purchase – Year 10	$3.519	$2.615	$2.315	$2.110	$2.354	$1.548	$1.402	$1.269
Maintenance Cost – Rampup	$8.013	$6.615	$6.317	$6.362	$4.606	$3.620	$3.657	$3.761
Total Maint Costs for Purchase – Year 1	$1.015	$0.838	$0.800	$0.806	$0.584	$0.459	$0.463	$0.477
Total Maint Costs for Purchase – Year 2	$0.961	$0.793	$0.757	$0.763	$0.552	$0.434	$0.439	$0.451
Total Maint Costs for Purchase – Year 3	$0.908	$0.750	$0.716	$0.721	$0.522	$0.410	$0.415	$0.426
Total Maint Costs for Purchase – Year 4	$0.860	$0.710	$0.678	$0.683	$0.494	$0.388	$0.392	$0.404
Total Maint Costs for Purchase – Year 5	$0.814	$0.672	$0.642	$0.646	$0.467	$0.367	$0.371	$0.382
Total Maint Costs for Purchase – Year 6	$0.769	$0.635	$0.607	$0.611	$0.442	$0.348	$0.351	$0.361
Total Maint Costs for Purchase – Year 7	$0.728	$0.601	$0.574	$0.578	$0.418	$0.329	$0.332	$0.342

	SA – 2024				SA – 2034			
	Ref	E	M	A	Ref	E	M	A
Total Maint Costs for Purchase – Year 8	$0.689	$0.569	$0.543	$0.547	$0.396	$0.311	$0.314	$0.323
Total Maint Costs for Purchase – Year 9	$0.651	$0.538	$0.513	$0.517	$0.375	$0.295	$0.298	$0.306
Total Maint Costs for Purchase – Year 10	$0.616	$0.509	$0.486	$0.489	$0.355	$0.279	$0.282	$0.290

TABLE O-17 – STA TOTAL OPERATIONAL MEAN COST (FUEL & MAINT)

	STA – 2024				STA – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Billions of USD								
Total Operational Expense	**$382.486**	**$281.743**	**$259.680**	**$228.439**	**$654.853**	**$441.026**	**$379.752**	**$363.317**
Fuel Cost	$339.589	$246.741	$226.628	$195.116	$590.761	$391.600	$330.006	$313.319
Total Fuel Costs for Purchase – Year 1	$26.865	$19.520	$17.929	$15.436	$46.753	$30.991	$26.117	$24.796
Total Fuel Costs for Purchase – Year 2	$28.275	$20.544	$18.869	$16.246	$49.205	$32.617	$27.487	$26.097
Total Fuel Costs for Purchase – Year 3	$29.703	$21.582	$19.823	$17.067	$51.606	$34.208	$28.828	$27.370
Total Fuel Costs for Purchase – Year 4	$31.151	$22.634	$20.789	$17.898	$54.236	$35.952	$30.297	$28.765
Total Fuel Costs for Purchase – Year 5	$32.812	$23.841	$21.898	$18.853	$57.028	$37.802	$31.857	$30.246
Total Fuel Costs for Purchase – Year 6	$34.481	$25.054	$23.011	$19.812	$59.949	$39.739	$33.488	$31.795
Total Fuel Costs for Purchase – Year 7	$36.199	$26.302	$24.158	$20.799	$63.041	$41.788	$35.215	$33.435
Total Fuel Costs for Purchase – Year 8	$38.024	$27.628	$25.375	$21.847	$66.160	$43.856	$36.958	$35.089
Total Fuel Costs for Purchase – Year 9	$40.053	$29.102	$26.730	$23.013	$69.554	$46.105	$38.853	$36.889
Total Fuel Costs for Purchase – Year 10	$42.025	$30.535	$28.046	$24.146	$73.229	$48.542	$40.907	$38.838
Maintenance Cost – Rampup	$42.897	$35.002	$33.052	$33.322	$64.092	$49.426	$49.747	$49.998
Total Maintenance Costs for Purchase – Year 1	$3.557	$2.902	$2.741	$2.763	$5.316	$4.100	$4.126	$4.147
Total Maintenance Costs for Purchase – Year 2	$3.708	$3.025	$2.857	$2.880	$5.541	$4.273	$4.301	$4.323
Total Maintenance Costs for Purchase – Year 3	$3.858	$3.148	$2.972	$2.997	$5.756	$4.439	$4.468	$4.490
Total Maintenance Costs for Purchase – Year 4	$4.007	$3.269	$3.087	$3.112	$5.991	$4.620	$4.650	$4.674
Total Maintenance Costs for Purchase – Year 5	$4.180	$3.411	$3.220	$3.247	$6.239	$4.811	$4.843	$4.867
Total Maintenance Costs for Purchase – Year 6	$4.350	$3.550	$3.352	$3.379	$6.496	$5.009	$5.042	$5.067
Total Maintenance Costs for Purchase – Year 7	$4.523	$3.691	$3.485	$3.514	$6.765	$5.217	$5.251	$5.277
Total Maintenance Costs for Purchase – Year 8	$4.705	$3.839	$3.625	$3.655	$7.032	$5.423	$5.458	$5.485
Total Maintenance Costs for Purchase – Year 9	$4.909	$4.005	$3.782	$3.813	$7.321	$5.646	$5.683	$5.711
Total Maintenance Costs for Purchase – Year 10	$5.101	$4.162	$3.930	$3.963	$7.634	$5.887	$5.925	$5.955
DISCOUNTED (9%) —Mean Costs in BY2013 Billions of USD								
Total Operational Expense	**$80.916**	**$59.575**	**$54.903**	**$48.262**	**$58.437**	**$39.335**	**$33.845**	**$32.372**
Fuel Cost	$72.164	$52.434	$48.159	$41.463	$52.914	$35.075	$29.558	$28.064
Total Fuel Costs for Purchase – Year 1	$8.453	$6.142	$5.641	$4.857	$6.200	$4.110	$3.464	$3.289
Total Fuel Costs for Purchase – Year 2	$8.162	$5.930	$5.447	$4.690	$5.987	$3.969	$3.344	$3.175
Total Fuel Costs for Purchase – Year 3	$7.866	$5.716	$5.250	$4.520	$5.761	$3.819	$3.218	$3.055
Total Fuel Costs for Purchase – Year 4	$7.569	$5.499	$5.051	$4.349	$5.554	$3.682	$3.103	$2.946
Total Fuel Costs for Purchase – Year 5	$7.314	$5.314	$4.881	$4.202	$5.358	$3.552	$2.993	$2.842
Total Fuel Costs for Purchase – Year 6	$7.051	$5.123	$4.706	$4.051	$5.167	$3.425	$2.887	$2.741
Total Fuel Costs for Purchase – Year 7	$6.791	$4.935	$4.532	$3.902	$4.985	$3.305	$2.785	$2.644
Total Fuel Costs for Purchase – Year 8	$6.545	$4.755	$4.368	$3.760	$4.800	$3.182	$2.681	$2.546
Total Fuel Costs for Purchase – Year 9	$6.325	$4.595	$4.221	$3.634	$4.629	$3.069	$2.586	$2.455
Total Fuel Costs for Purchase – Year 10	$6.088	$4.424	$4.063	$3.498	$4.472	$2.964	$2.498	$2.372
Maintenance Cost – Rampup	$8.752	$7.141	$6.743	$6.798	$5.523	$4.259	$4.287	$4.309
Total Maintenance Costs for Purchase – Year 1	$1.067	$0.871	$0.822	$0.829	$0.674	$0.520	$0.523	$0.526
Total Maintenance Costs for Purchase – Year 2	$1.021	$0.833	$0.786	$0.793	$0.644	$0.497	$0.500	$0.503
Total Maintenance Costs for Purchase – Year 3	$0.974	$0.795	$0.751	$0.757	$0.614	$0.473	$0.477	$0.479
Total Maintenance Costs for Purchase – Year 4	$0.928	$0.757	$0.715	$0.721	$0.586	$0.452	$0.455	$0.457
Total Maintenance Costs for Purchase – Year 5	$0.888	$0.725	$0.684	$0.690	$0.560	$0.432	$0.435	$0.437
Total Maintenance Costs for Purchase – Year 6	$0.848	$0.692	$0.654	$0.659	$0.535	$0.413	$0.415	$0.417
Total Maintenance Costs for Purchase – Year 7	$0.809	$0.660	$0.623	$0.629	$0.511	$0.394	$0.397	$0.399

	STA – 2024				STA – 2034			
	Ref	E	M	A	Ref	E	M	A
Total Maintenance Costs for Purchase – Year 8	$0.772	$0.630	$0.595	$0.600	$0.487	$0.376	$0.378	$0.380
Total Maintenance Costs for Purchase – Year 9	$0.739	$0.603	$0.569	$0.574	$0.466	$0.359	$0.361	$0.363
Total Maintenance Costs for Purchase – Year 10	$0.705	$0.575	$0.543	$0.547	$0.445	$0.344	$0.346	$0.348

TABLE O-18 – RJ TOTAL OPERATIONAL MEAN COST (FUEL & MAINT)

	RJ – 2024				RJ – 2034			
	Ref	E	M	A	Ref	E	M	A
UNDISCOUNTED—Mean Costs in BY2013 Billions of USD								
Total Operational Expense	**$41.625**	**$31.237**	**$29.397**	**$27.068**	**$75.814**	**$53.363**	**$48.710**	**$45.308**
Fuel Cost	$34.697	$25.076	$23.264	$20.903	$64.178	$43.055	$38.363	$34.828
Total Fuel Costs for Purchase – Year 1	$2.581	$1.865	$1.731	$1.555	$4.776	$3.204	$2.855	$2.592
Total Fuel Costs for Purchase – Year 2	$2.745	$1.984	$1.841	$1.654	$5.090	$3.415	$3.043	$2.762
Total Fuel Costs for Purchase – Year 3	$2.912	$2.105	$1.953	$1.754	$5.410	$3.629	$3.234	$2.936
Total Fuel Costs for Purchase – Year 4	$3.117	$2.253	$2.090	$1.878	$5.774	$3.874	$3.452	$3.134
Total Fuel Costs for Purchase – Year 5	$3.327	$2.404	$2.230	$2.004	$6.145	$4.123	$3.674	$3.335
Total Fuel Costs for Purchase – Year 6	$3.539	$2.558	$2.373	$2.132	$6.523	$4.376	$3.899	$3.540
Total Fuel Costs for Purchase – Year 7	$3.756	$2.715	$2.518	$2.263	$6.908	$4.634	$4.129	$3.749
Total Fuel Costs for Purchase – Year 8	$3.977	$2.874	$2.666	$2.396	$7.380	$4.951	$4.412	$4.005
Total Fuel Costs for Purchase – Year 9	$4.238	$3.063	$2.842	$2.553	$7.820	$5.246	$4.675	$4.244
Total Fuel Costs for Purchase – Year 10	$4.505	$3.256	$3.020	$2.714	$8.351	$5.602	$4.992	$4.532
Maintenance Cost – Rampup	$6.929	$6.160	$6.133	$6.165	$11.636	$10.308	$10.347	$10.481
Total Maintenance Costs for Purchase – Year 1	$0.541	$0.481	$0.479	$0.481	$0.908	$0.805	$0.808	$0.818
Total Maintenance Costs for Purchase – Year 2	$0.570	$0.506	$0.504	$0.507	$0.959	$0.849	$0.853	$0.864
Total Maintenance Costs for Purchase – Year 3	$0.598	$0.532	$0.530	$0.532	$1.009	$0.894	$0.897	$0.909
Total Maintenance Costs for Purchase – Year 4	$0.634	$0.564	$0.562	$0.565	$1.067	$0.945	$0.949	$0.961
Total Maintenance Costs for Purchase – Year 5	$0.671	$0.596	$0.593	$0.597	$1.125	$0.996	$1.000	$1.013
Total Maintenance Costs for Purchase – Year 6	$0.707	$0.628	$0.625	$0.629	$1.182	$1.047	$1.051	$1.065
Total Maintenance Costs for Purchase – Year 7	$0.743	$0.660	$0.657	$0.661	$1.240	$1.098	$1.103	$1.117
Total Maintenance Costs for Purchase – Year 8	$0.779	$0.692	$0.689	$0.693	$1.312	$1.162	$1.167	$1.182
Total Maintenance Costs for Purchase – Year 9	$0.822	$0.731	$0.727	$0.731	$1.377	$1.220	$1.224	$1.240
Total Maintenance Costs for Purchase – Year 10	$0.865	$0.769	$0.766	$0.770	$1.456	$1.290	$1.295	$1.312
DISCOUNTED (9%) —Mean Costs in BY2013 Billions of USD								
Total Operational Expense	**$8.751**	**$6.558**	**$6.168**	**$5.675**	**$6.738**	**$4.734**	**$4.317**	**$4.012**
Fuel Cost	$7.350	$5.312	$4.928	$4.428	$5.743	$3.853	$3.433	$3.117
Total Fuel Costs for Purchase – Year 1	$0.817	$0.590	$0.548	$0.492	$0.638	$0.428	$0.382	$0.346
Total Fuel Costs for Purchase – Year 2	$0.797	$0.576	$0.534	$0.480	$0.624	$0.419	$0.373	$0.339
Total Fuel Costs for Purchase – Year 3	$0.775	$0.560	$0.520	$0.467	$0.609	$0.408	$0.364	$0.330
Total Fuel Costs for Purchase – Year 4	$0.762	$0.550	$0.511	$0.459	$0.596	$0.400	$0.356	$0.323
Total Fuel Costs for Purchase – Year 5	$0.746	$0.539	$0.500	$0.449	$0.582	$0.390	$0.348	$0.316
Total Fuel Costs for Purchase – Year 6	$0.728	$0.526	$0.488	$0.438	$0.567	$0.380	$0.339	$0.307
Total Fuel Costs for Purchase – Year 7	$0.709	$0.512	$0.475	$0.427	$0.550	$0.369	$0.329	$0.299
Total Fuel Costs for Purchase – Year 8	$0.688	$0.497	$0.461	$0.415	$0.540	$0.362	$0.323	$0.293
Total Fuel Costs for Purchase – Year 9	$0.673	$0.486	$0.451	$0.405	$0.525	$0.352	$0.314	$0.285
Total Fuel Costs for Purchase – Year 10	$0.656	$0.474	$0.440	$0.395	$0.514	$0.345	$0.307	$0.279
Maintenance Cost – Rampup	$1.401	$1.246	$1.240	$1.247	$0.994	$0.881	$0.884	$0.896
Total Maintenance Costs for Purchase – Year 1	$0.162	$0.144	$0.144	$0.144	$0.115	$0.102	$0.102	$0.104
Total Maintenance Costs for Purchase – Year 2	$0.157	$0.139	$0.139	$0.139	$0.111	$0.099	$0.099	$0.100
Total Maintenance Costs for Purchase – Year 3	$0.151	$0.134	$0.134	$0.134	$0.108	$0.095	$0.096	$0.097
Total Maintenance Costs for Purchase – Year 4	$0.147	$0.131	$0.130	$0.131	$0.104	$0.093	$0.093	$0.094
Total Maintenance Costs for Purchase – Year 5	$0.143	$0.127	$0.126	$0.127	$0.101	$0.089	$0.090	$0.091
Total Maintenance Costs for Purchase – Year 6	$0.138	$0.122	$0.122	$0.123	$0.097	$0.086	$0.087	$0.088
Total Maintenance Costs for Purchase – Year 7	$0.133	$0.118	$0.118	$0.118	$0.094	$0.083	$0.083	$0.084

	RJ – 2024				RJ – 2034			
	Ref	E	M	A	Ref	E	M	A
Total Maintenance Costs for Purchase – Year 8	$0.128	$0.114	$0.113	$0.114	$0.091	$0.081	$0.081	$0.082
Total Maintenance Costs for Purchase – Year 9	$0.124	$0.110	$0.110	$0.110	$0.088	$0.078	$0.078	$0.079
Total Maintenance Costs for Purchase – Year 10	$0.120	$0.106	$0.106	$0.106	$0.085	$0.075	$0.076	$0.077

Average Operator Expense

TABLE O-19 – AVERAGE OPERATOR EXPENSE (MEAN COST) SA

	SA – 2024				SA – 2034			
	Ref	E	M	A	Ref	E	M	A
DISCOUNTED (9%) —Average Costs in Millions of USD								
Avg Operator Expense per A/C—Over All A/C for Ops Years	**$13**	**$10**	**$9**	**$8**	**$6**	**$4**	**$4**	**$4**
Avg Fuel Cost per A/C—Over All A/C for Ops Yrs	$11	$8	$7	$7	$5	$4	$3	$3
Avg Maintenance Cost per A/C—Over All A/C for Ops Years	$2	$2	$2	$2	$1	$1	$1	$1
Avg Operator Expense per A/C—Over First A/C Purchase for Ops Years	**$18**	**$14**	**$12**	**$11**	**$9**	**$6**	**$5**	**$5**
Avg Fuel Cost per A/C—Over First A/C Purchase for Ops Years	$15	$11	$10	$9	$7	$5	$4	$4
Avg Maintenance Cost per A/C—Over First A/C Purchase for Ops Years	$3	$2	$2	$2	$1	$1	$1	$1

TABLE O-20 – AVERAGE OPERATOR EXPENSE (MEAN COST) STA

	STA – 2024				STA – 2034			
	Ref	E	M	A	Ref	E	M	A
DISCOUNTED (9%) —Average Costs in Millions of USD								
Avg Operator Expense per A/C—Over All A/C for Ops Years	**$57**	**$42**	**$39**	**$34**	**$27**	**$18**	**$16**	**$15**
Avg Fuel Cost per A/C—Over All A/C for Ops Years	$51	$37	$34	$29	$25	$16	$14	$13
Avg Maintenance Cost per A/C—Over All A/C for Ops Years	$6	$5	$5	$5	$3	$2	$2	$2
Avg Operator Expense per A/C—Over First A/C Purchase for Ops Years	**$79**	**$58**	**$54**	**$47**	**$38**	**$26**	**$22**	**$21**
Avg Fuel Cost per A/C—Over First A/C Purchase for Ops Years	$70	$51	$47	$40	$34	$23	$19	$18
Avg Maintenance Cost per A/C—Over First A/C Purchase for Ops Years	$9	$7	$7	$7	$4	$3	$3	$3

TABLE O-21 – AVERAGE OPERATOR EXPENSE (MEAN COST) RJ

	RJ – 2024				RJ – 2034			
	Ref	E	M	A	Ref	E	M	A
DISCOUNTED (9%) —Average Costs in Millions of USD								
Avg Operator Expense per A/C—Over All A/C for Ops Years	**$10**	**$7**	**$7**	**$6**	**$5**	**$3**	**$3**	**$3**
Avg Fuel Cost per A/C—Over All A/C for Ops Years	$8	$6	$5	$5	$4	$3	$2	$2
Avg Maintenance Cost per A/C—Over All A/C for Ops Years	$2	$1	$1	$1	$1	$1	$1	$1
Avg Operator Expense per A/C—Over First A/C Purchase for Ops Years	**$13**	**$10**	**$9**	**$9**	**$6**	**$4**	**$4**	**$4**

	RJ – 2024				RJ – 2034			
	Ref	E	M	A	Ref	E	M	A
Avg Fuel Cost per A/C—Over First A/C Purchase for Ops Years	$11	$8	$8	$7	$5	$4	$3	$3
Avg Maintenance Cost per A/C—Over First A/C Purchase for Ops Years	$2	$2	$2	$2	$1	$1	$1	$1

APPENDIX P—Sensitivity Analyses Results

Several sensitivity analyses on key parameter in the study were conducted. This appendix provides results for each of the three aircraft class configurations for the 2024 EIS and 2034 EIS years. For each sensitivity analysis the relative percent delta for the scenario as compared to the reference cost is plotted. A factor of "1.0" means that the cost for the scenario is the same as the reference cost and implies that if an operator were to procure this technology infused aircraft if would not incur additional costs nor decrease their overall cost expense. Each chart shows the results for each EIS scenario (i.e., Evolutionary, Moderate, and Aggressive) and determines a trend line through the data points to project cost impacts versus fuel reduction achievement for points not analyzed in the study. These lines represent a space for where in each vehicle class we can project at what level of fuel reduction a vehicle can be attractive to operators in the market. The point where the trend line crosses the "1.0" reference line is the maximum estimated fuel reduction that can be achieved that does not impose an increased cost impact to an operator.

Technical Parameters

The analysis relies heavily on technical parameters to drive the cost estimating algorithms. These parameters consist of mass, design heritage, design complexity, and production complexity. Ranges for these values were identified by the SMEs and used within the study to bound the results during probabilistic simulation.

For this sensitivity analysis the model was run with three cases. The first case is the baseline results with uncertainty on. The second case is with all technical parameters chosen on the high end of the spectrum, meaning the most pessimistic case. The third case is with all technical parameters chosen on the low end of the range, meaning the most optimistic case.

The graphs in Figure P-1 and Figure P-2 show the estimated results for the scenario where the low bounds of the technical parameters are used. These low bounds relate to a low mass, a high level of re-use, and low complexity. The results from this sensitivity suggest that if the fuel reduction can be achieved at this extreme scenario then in the 2024 time frame fuel burn reductions up to 35% can be achieved and in the 2034 EIS period even significantly higher (>50%) can be cost beneficial to an operator.

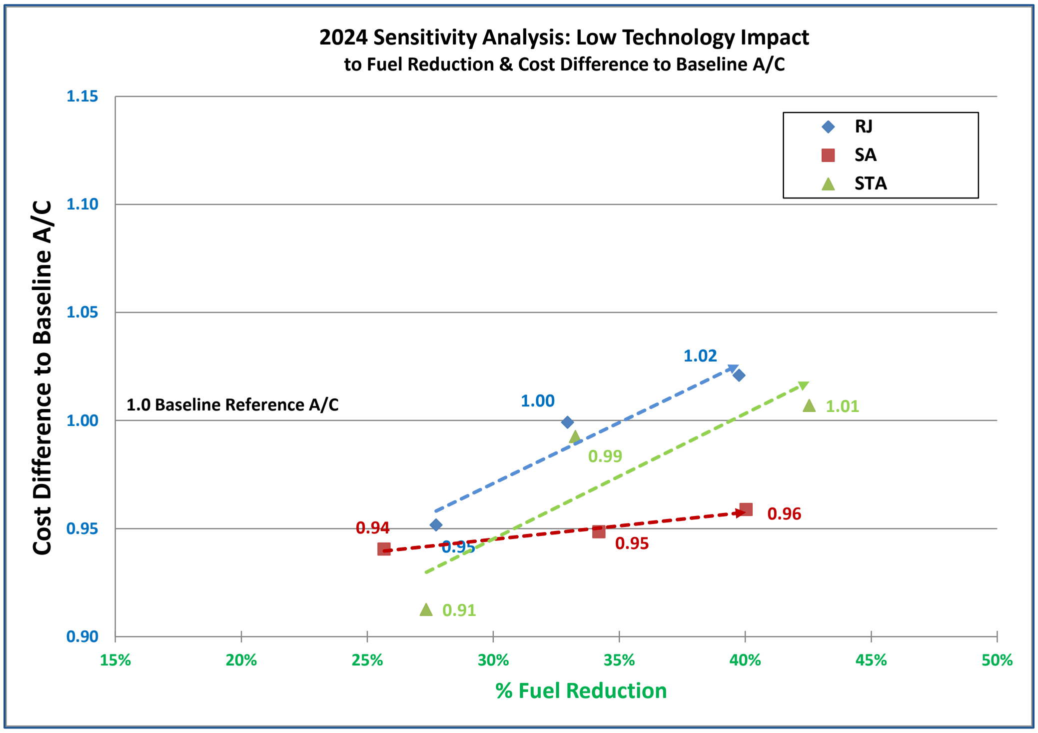


FIGURE P-1 – TECHNICAL SENSITIVITY ANALYSIS – 2024 EIS—LOW TECHNICAL PARAMETERS (SA, STA, AND RJ)

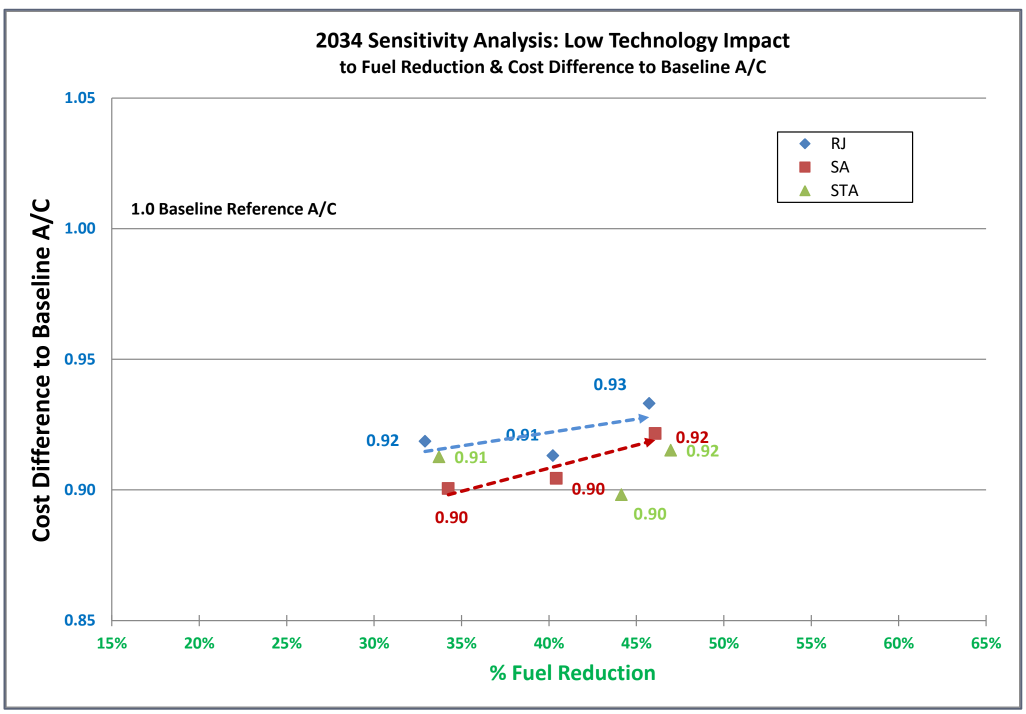


FIGURE P-2 – TECHNICAL SENSITIVITY ANALYSIS – 2034 EIS—LOW TECHNICAL PARAMETERS (SA, STA, AND RJ)

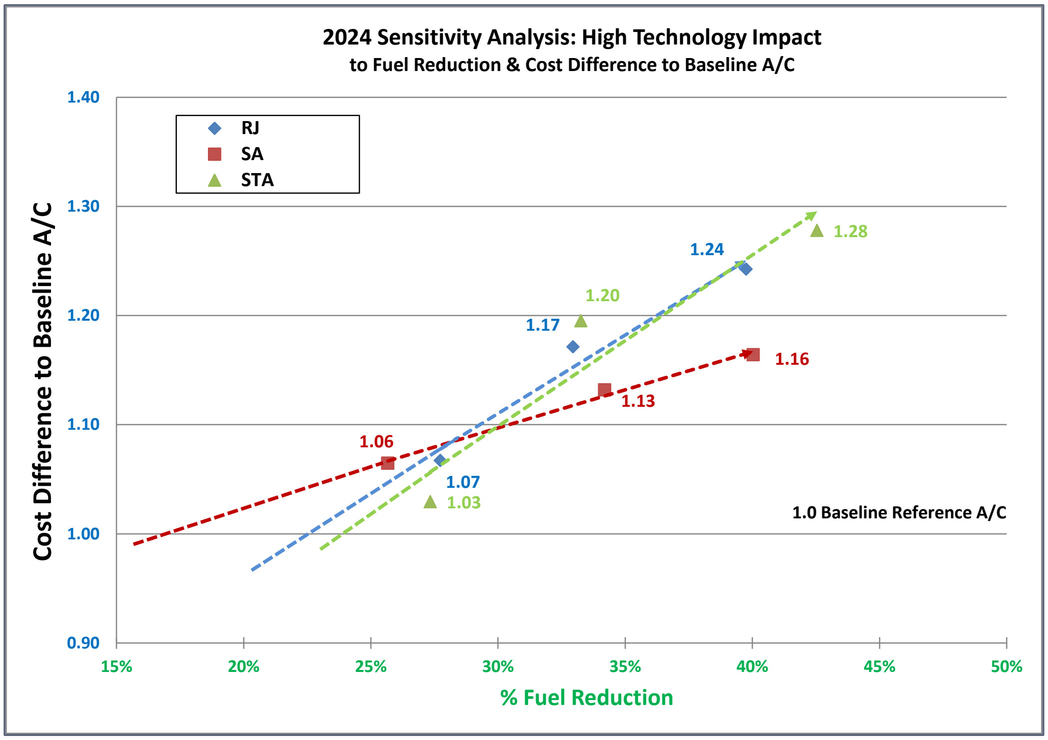


FIGURE P-3 – TECHNICAL SENSITIVITY ANALYSIS – 2024 EIS—HIGH TECHNICAL PARAMETERS (SA, STA, AND RJ)

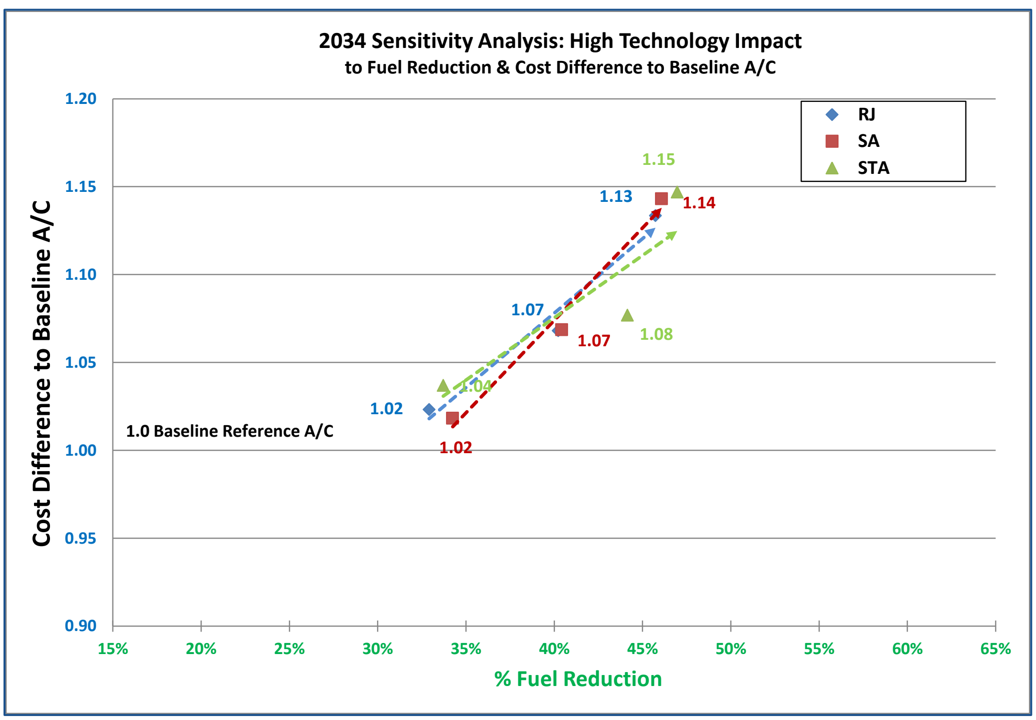


FIGURE P-4 – TECHNICAL SENSITIVITY ANALYSIS – 2034 EIS—HIGH TECHNICAL PARAMETERS (SA, STA, AND RJ)

Maintenance Parameters

For maintenance costs, four parameters are drivers. These parameters are maintenance complexity, airframe maintenance interval, engine complexity, and engine maintenance interval One case is with all maintenance parameters chosen to on the bound that drives a higher overall cost, meaning the most pessimistic case. For this case, the maintenance complexity would be the high bound value and maintenance interval would the low range value. The other case is with all technical parameters chosen on the low wind of the range, meaning the most optimistic case.

In reviewing the results shown in Figure P-5, Figure P-6, Figure P-7, and Figure P-8 illustrate that for the RJ and STA aircraft types, maintenance has little impact between the extreme scenarios on changing the costs to an operator for the 2024 EIS timeframe. The SA vehicle is shown to be a little more sensitive to changes in maintenance assumptions for the 2024 EIS timeframe. In all aircraft types for the 2034 EIS timeframe, changes in maintenance assumption have little impact.

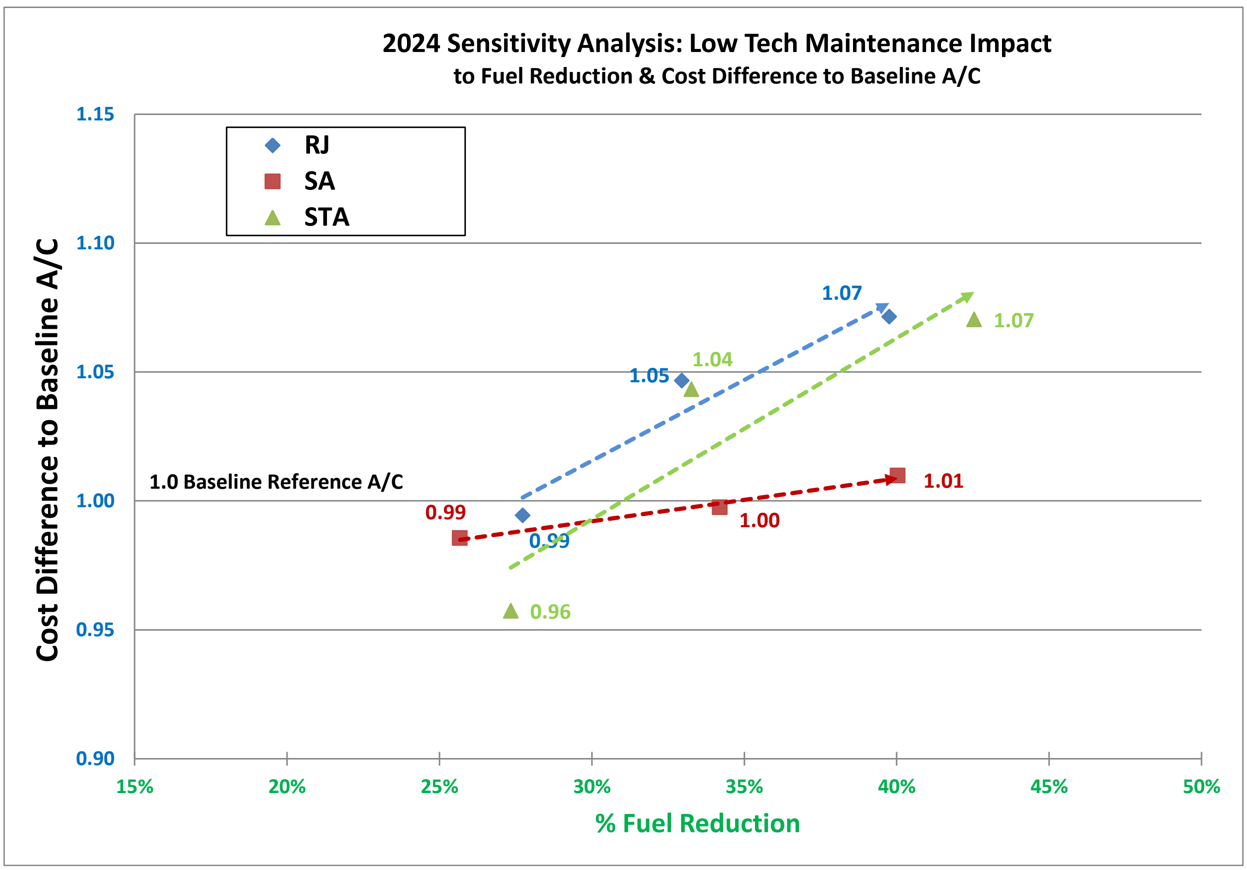


FIGURE P-5 – MAINTENANCE SENSITIVITY ANALYSIS – 2024 EIS —LOW TECHNICAL PARAMETERS (SA, STA, AND RJ)

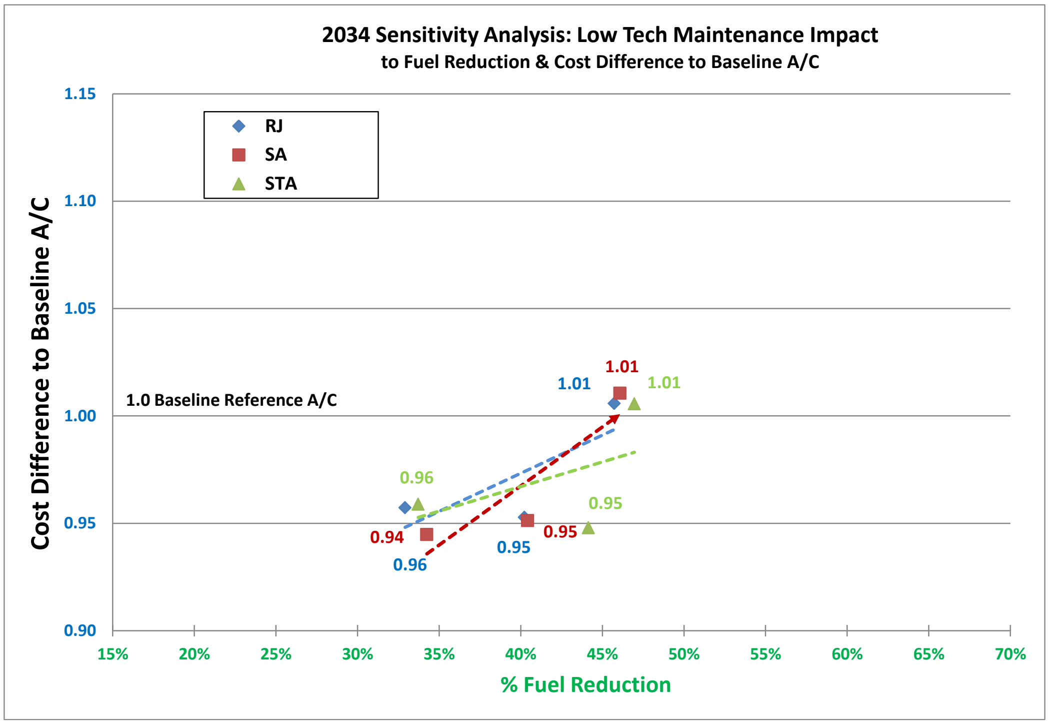


FIGURE P-6 – MAINTENANCE SENSITIVITY ANALYSIS – 2034 EIS—LOW TECHNICAL PARAMETERS (SA, STA, AND RJ)

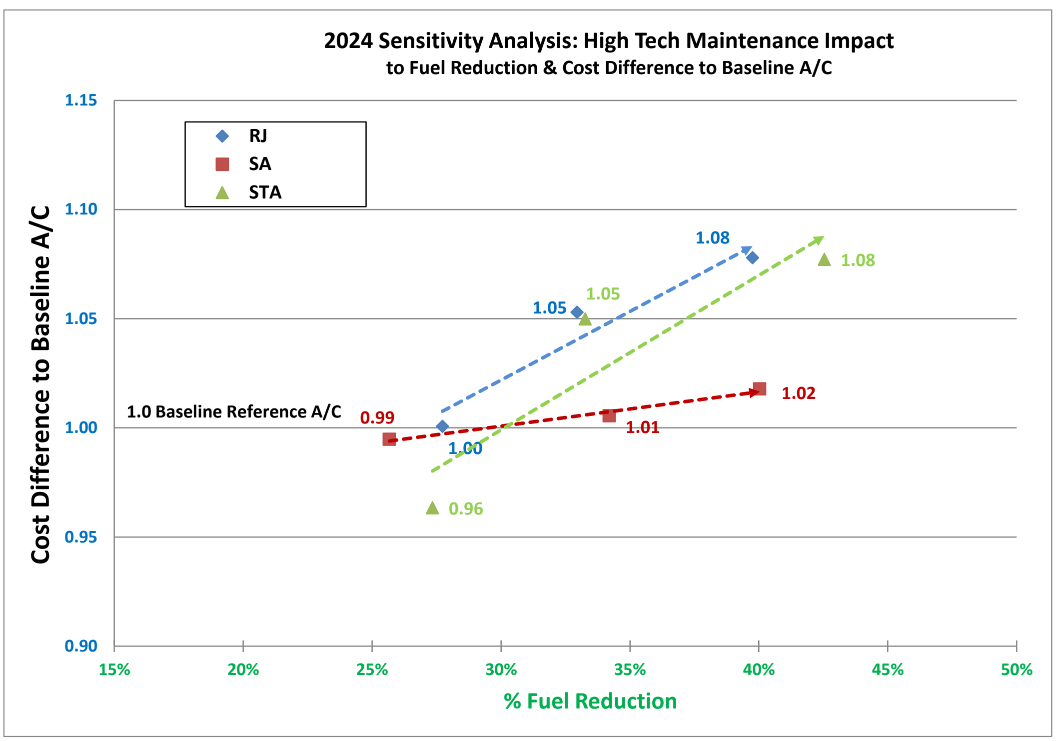


FIGURE P-7 – MAINTENANCE SENSITIVITY ANALYSIS -2024 EIS—HIGH TECHNICAL PARAMETERS (SA, STA, AND RJ)

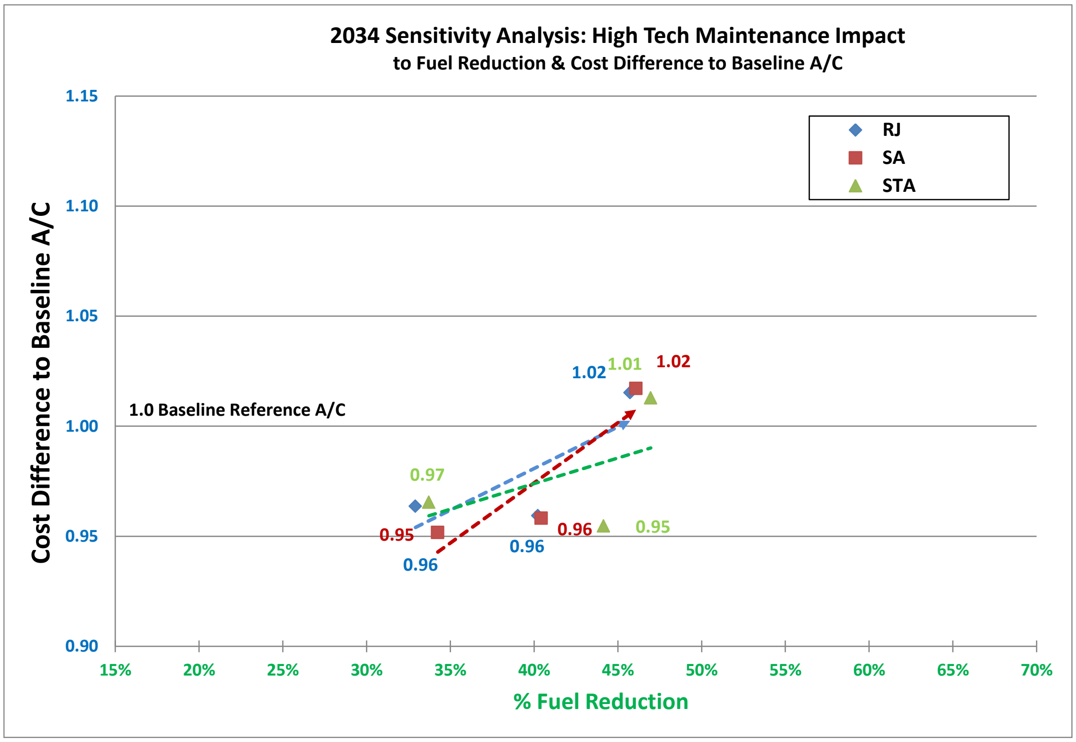


FIGURE P-8 – MAINTENANCE SENSITIVITY ANALYSIS -2034 EIS—HIGH TECHNICAL PARAMETERS (SA, STA, AND RJ)

Market Capture

A key parameter of the analysis is the overall size of the operational fleet. In the analysis the size of the fleet is driven by the quantity of aircraft assumed to be procured and operated. Driving this analysis are two parameters; 1) the overall market demand; and 2) the overall market capture. Sensitivity on market capture was conducted to assess how increased or decreased demand could affect the ROI for an operator, three scenarios were conducted for each aircraft and EIS year. The scenarios were to look at two reductions in quantity—one at a 50% reduction and the other at 20% reduction. The last scenario was to look at a 20% increase in market capture.

Figure P-9 and Figure P-10 shows the extreme case where an operator only captures 50% less of the market than estimated in the baseline study results. This would reflect a 19% capture from an operator for the SA market, instead of the 38% identified for this study. The STA and RJ market captures are also adjusted accordingly. In this scenario, an operator may be willing to accept up an aircraft that can achieve up to a 15% fuel reduction. This is interesting in that several recently identified aircraft coming in the 2024 timeframe (i.e., A32-NEO) are indicating fuel burn reduction of 12-15%.

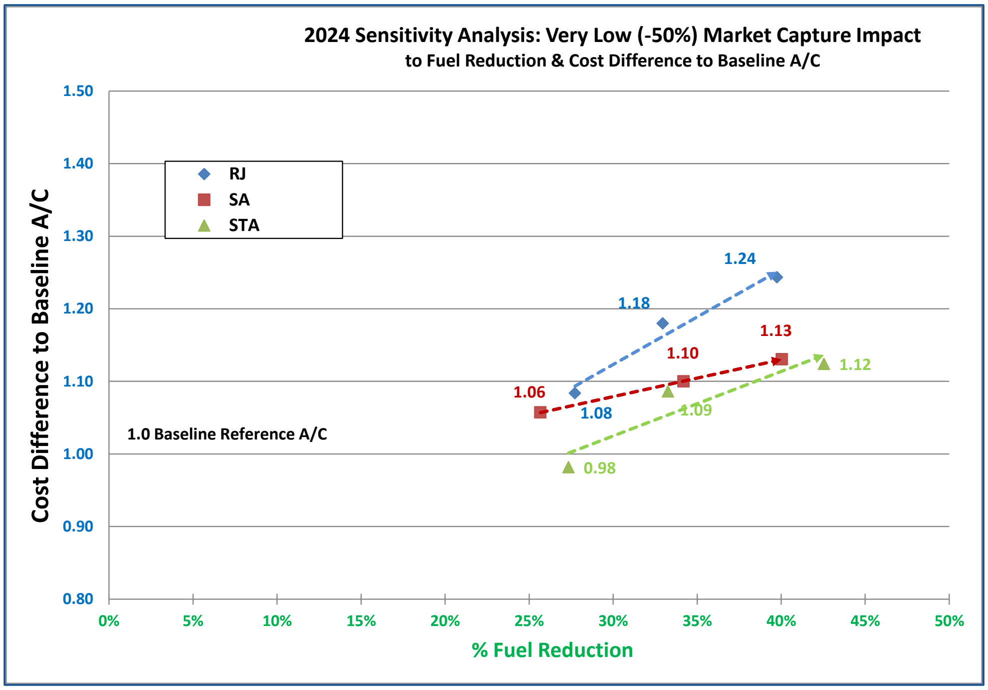


FIGURE P-9 – MARKET CAPTURE SENSITIVITY ANALYSIS – 2024 EIS —VERY PESSIMISTIC (50% REDUCTION) MARKET CAPTURE (SA, STA, AND RJ)

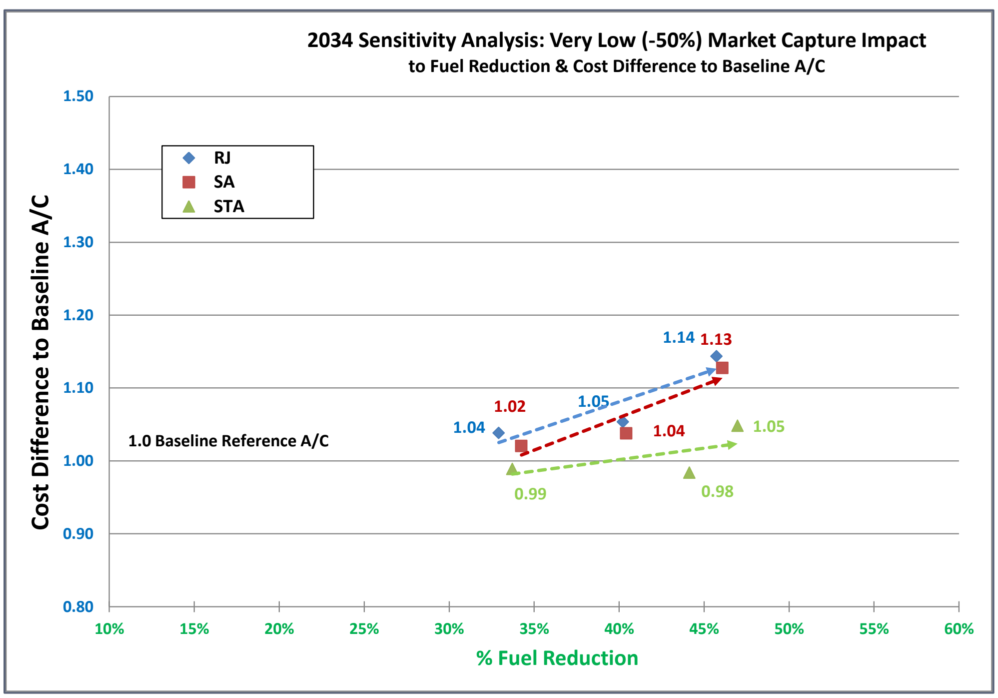


FIGURE P-10 – MARKET CAPTURE SENSITIVITY ANALYSIS – 2034 EIS —VERY PESSIMISTIC (50% REDUCTION) MARKET CAPTURE (SA, STA, AND RJ)

The resulting Figure P-11, Figure P-12, Figure P-13, and Figure P-4 show the study results given various levels of change to the market capture. As expected, as the market capture increases the overall operator costs for a vehicle with a specific fuel burn reduction decrease. This sensitivity went to a maximum increase of 20%, which equated to a market capture of approximately 46% for SA, and indicates that a maximum fuel reduction of up to 31% may be attractive in the market.

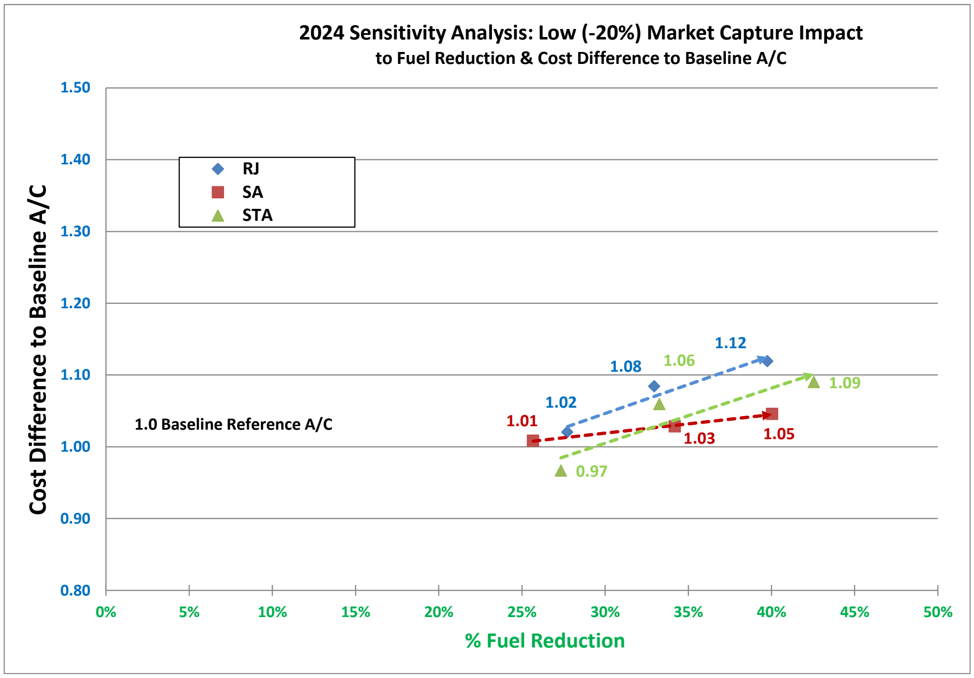


FIGURE P-11 – MARKET CAPTURE SENSITIVITY ANALYSIS – 2024 EIS —PESSIMISTIC (20% REDUCTION) MARKET CAPTURE (SA, STA, AND RJ)

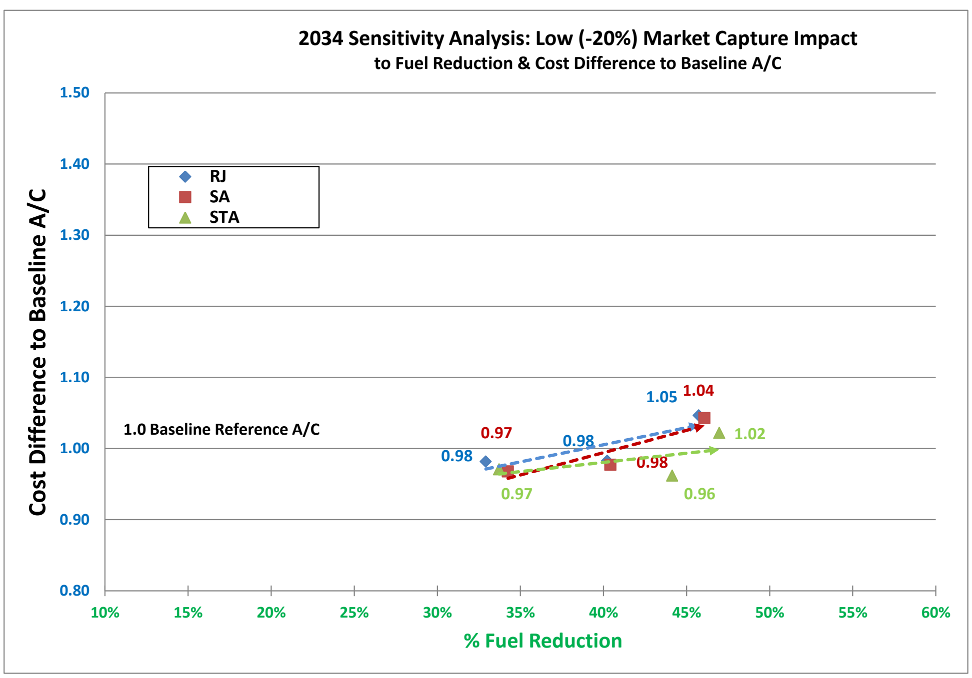


FIGURE P-12 – MARKET CAPTURE SENSITIVITY ANALYSIS—2034 EIS – PESSIMISTIC (20% REDUCTION) MARKET CAPTURE (SA, STA, AND RJ)

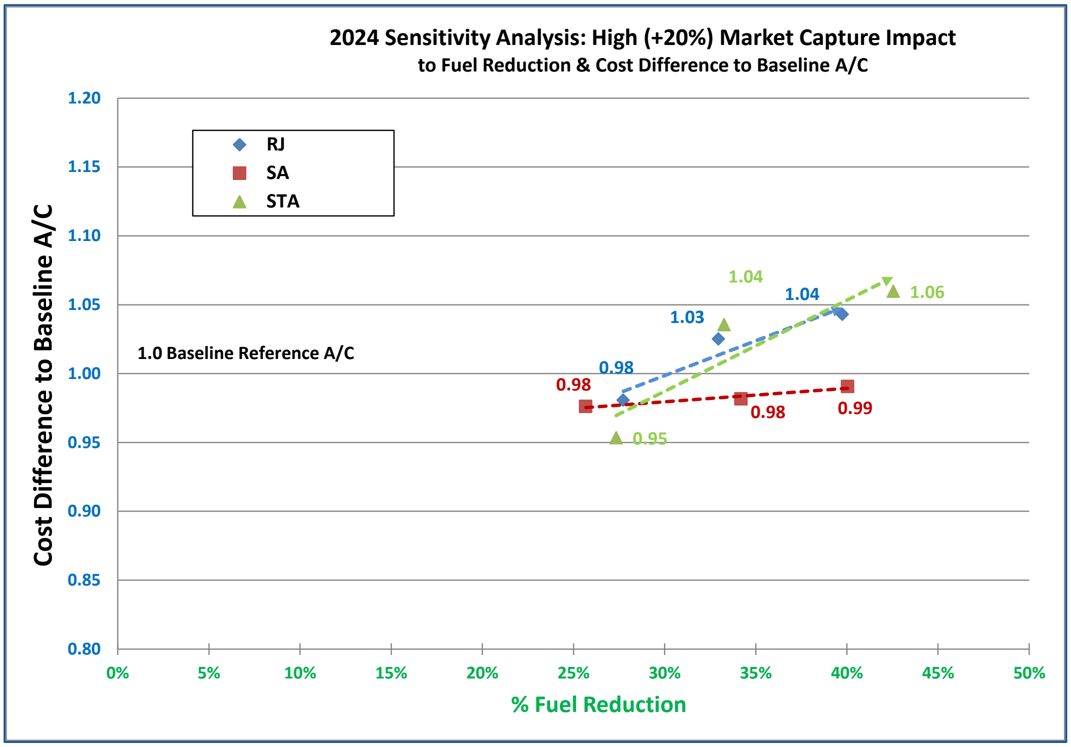


FIGURE P-13 – MARKET CAPTURE SENSITIVITY ANALYSIS – 2024 EIS—OPTIMISTIC (20% INCREASE) MARKET CAPTURE (SA, STA, AND RJ)

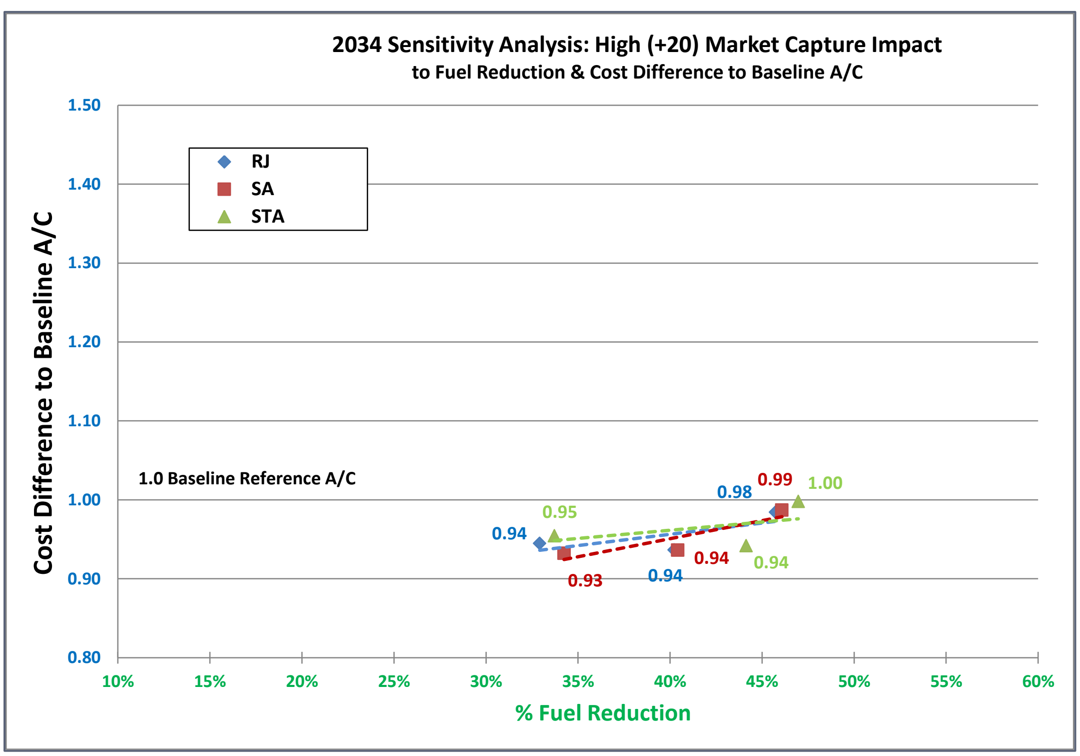


FIGURE P-14 – MARKET CAPTURE SENSITIVITY ANALYSIS – 2034 EIS—OPTIMISTIC (20% INCREASE) MARKET CAPTURE (SA, STA, AND RJ)

Annual Fuel Price Increase Sensitivity

As fuel is a key driver and there is uncertainty in future prices, considering the impact if fuel were to increase or decrease is an important sensitivity. Currently the base assumption in the model is an approximate 1% per annum real increase in fuel prices. If fuel prices were to increase at a higher rate the study results will show a higher benefit for the aircraft. Conversely, if fuel prices were to decrease the benefit derived from fuel reduction will be minimized. A sensitivity analysis was done to show the impact if gas were to deviate +/- 2% around the base assumption. The high range of fuel prices was done at a 3% per annum increase and the low range was set to a -1% per annum fuel increase (ongoing fuel price reduction).

As fuel costs are a major portion of the Total Operator Cost, it is expected that this sensitivity should have a dramatic impact on the fuel reduction point for which an aircraft may be attractive to an operator. Figure P-8 shows that if fuel prices continue to decrease then the economic incentive for procuring aircraft infused with fuel-burn reduction technology is diminished. In the 2024 EIS analysis it shows that this point may move to a 16% fuel-burn reduction level, and in the 2034 timeframe to a 21% fuel-burn reduction level. This indicates that given a deflationary environment for fuel the economic attractiveness tops out at a lower level and other incentive are needed for the operator market.

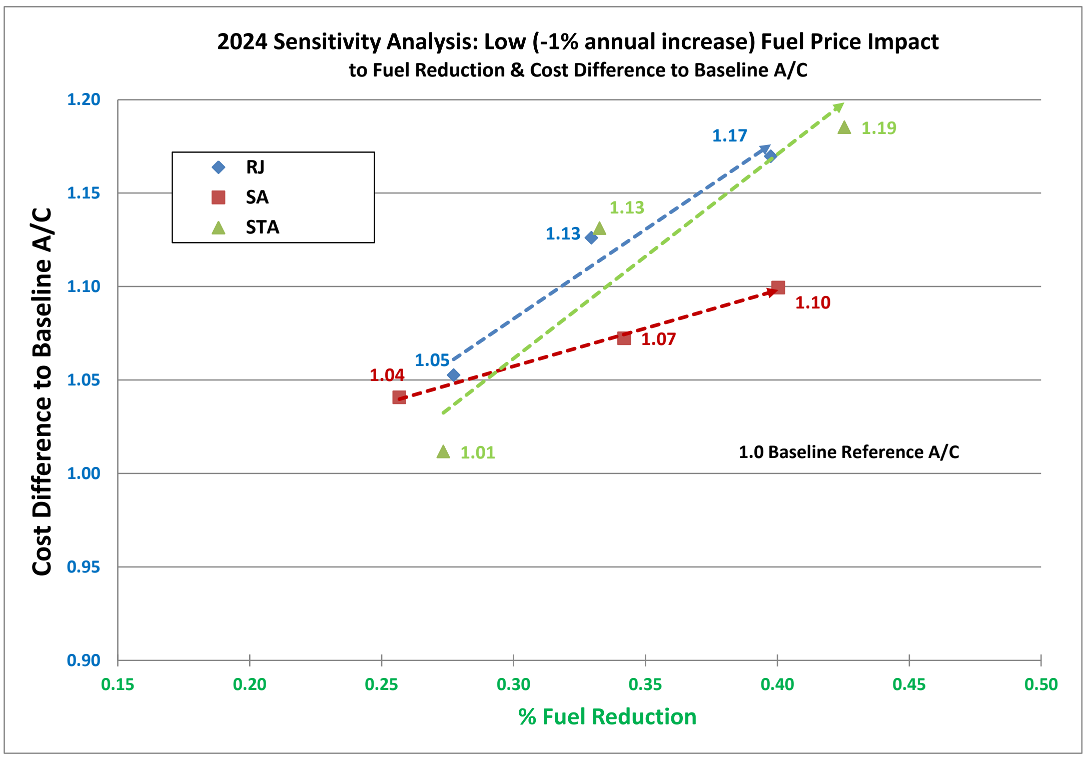


FIGURE P-15 – FUEL PRICE INCREASE SENSITIVITY ANALYSIS – 2024 EIS—LOW (-1% INCREASE PER YEAR) MARKET CAPTURE (SA, STA, AND RJ)

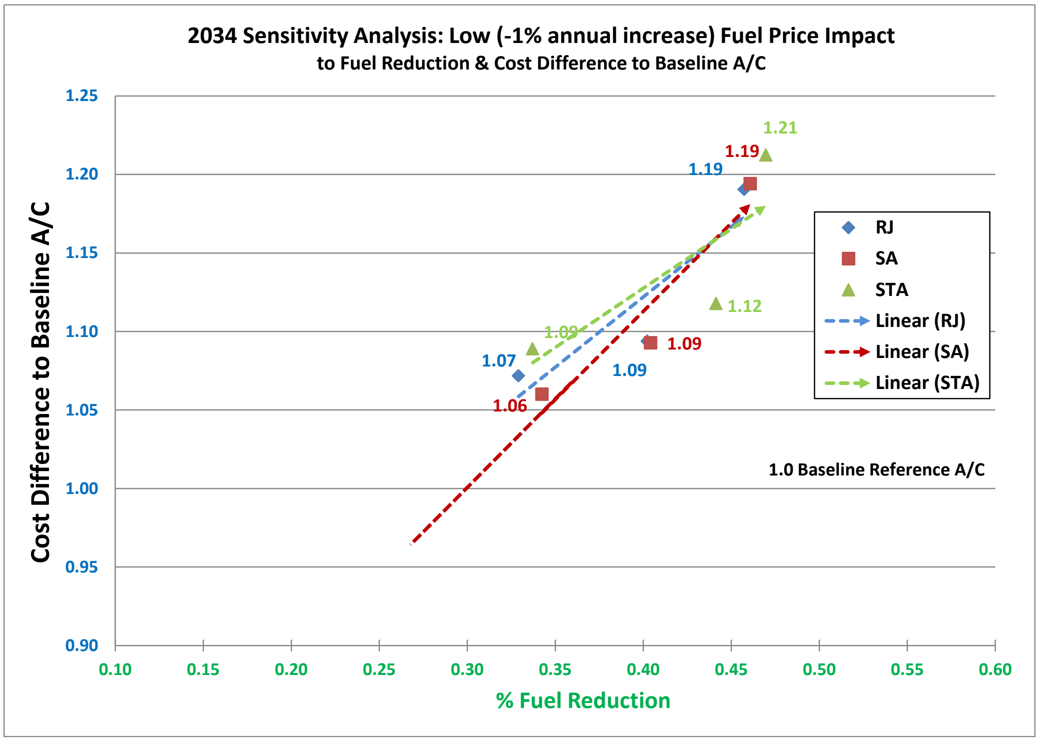


FIGURE P-16 – FUEL PRICE INCREASE SENSITIVITY ANALYSIS – 2034 EIS—LOW (-1% INCREASE PER YEAR) MARKET CAPTURE (SA, STA, AND RJ)

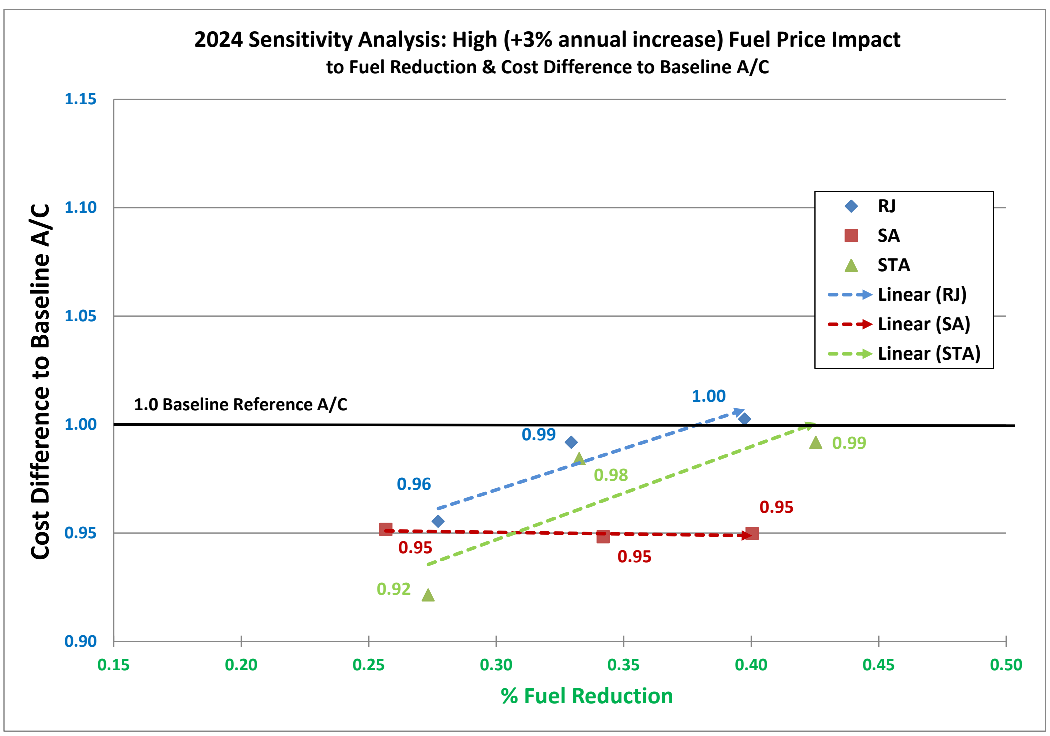


FIGURE P-17 – FUEL PRICE INCREASE SENSITIVITY ANALYSIS – 2024 EIS—HIGH (+3% INCREASE PER YEAR) MARKET CAPTURE (SA, STA, AND RJ)

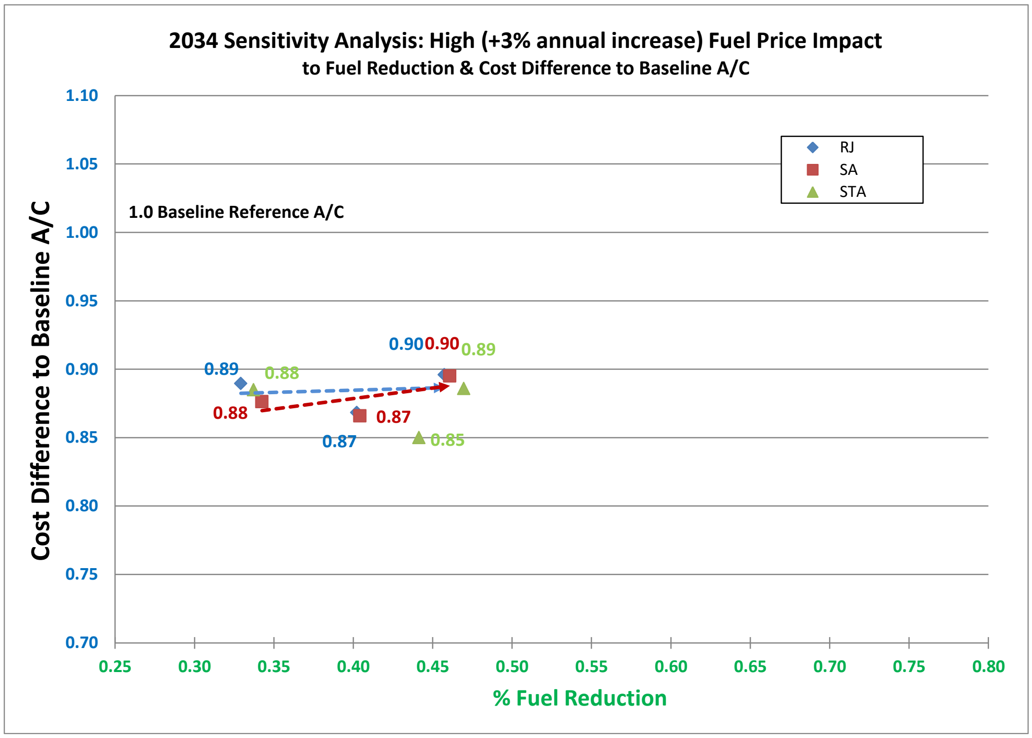


FIGURE P-18 – FUEL PRICE INCREASE SENSITIVITY ANALYSIS – 2034 EIS—HIGH (+3% INCREASE PER YEAR) MARKET CAPTURE (SA, STA, AND RJ)

Discount Rate Sensitivity

This analysis looks at the range of the impact by changing the discount rates and calculating the overall results to determine where a potential fuel-burn reduction aircraft will cost less over a seven-year operational life than a vehicle with current performance characteristics. The discount rate is important as it varies by company and is in line with the internal rate of return they are looking at for investment of their funds. Companies with risk adverse postures or who have high returns on their investments will lean toward a higher discount rate for their analysis as they place tremendous value on their cash and feel that there are more lucrative investment options.

Given the potential variation between operators for discount rate a wide range of sensitivities were run to capture from a regulatory Government perspective of 3% up to a rate of 15%. This provides a wide span and allows the ability to develop a curve over this range to assess the overall study sensitivity to discount rate. The following figures indicate that as discount rate is decreased there is an underlying cost benefit in pursuing more aggressive fuel-burn reducing aircraft. The sensitivity indicates that an aircraft with up to 19% fuel burn reduction can be attractive even considering a 15% discount rate. The 3% discount level shows the maximum operator cost threshold calculated by the study on fuel-burn reduction to be approximately 33%. Figure P-19, Figure P-20, Figure P-21, Figure P-22, Figure P-23, Figure P-24, Figure P-25, and Figure P-25 illustrate the impact of the various discount rates for the 2024 and 2034 EIS periods.

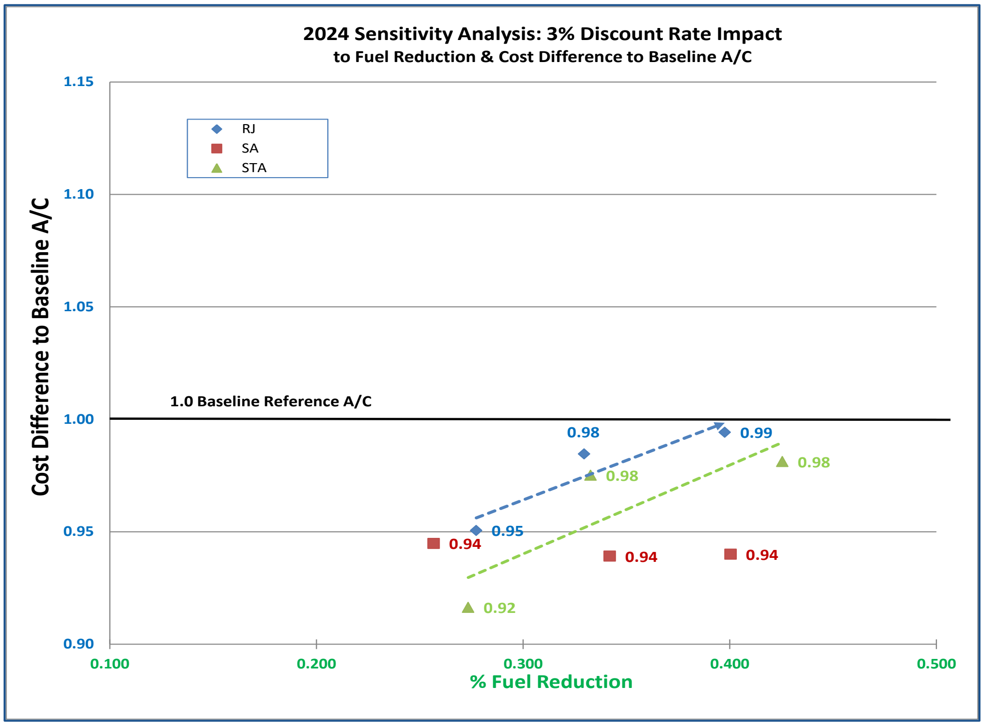


FIGURE P-19 – DISCOUNT RATE SENSITIVITY ANALYSIS – 2024 EIS — 3% DISCOUNT RATE (SA, STA, AND RJ)

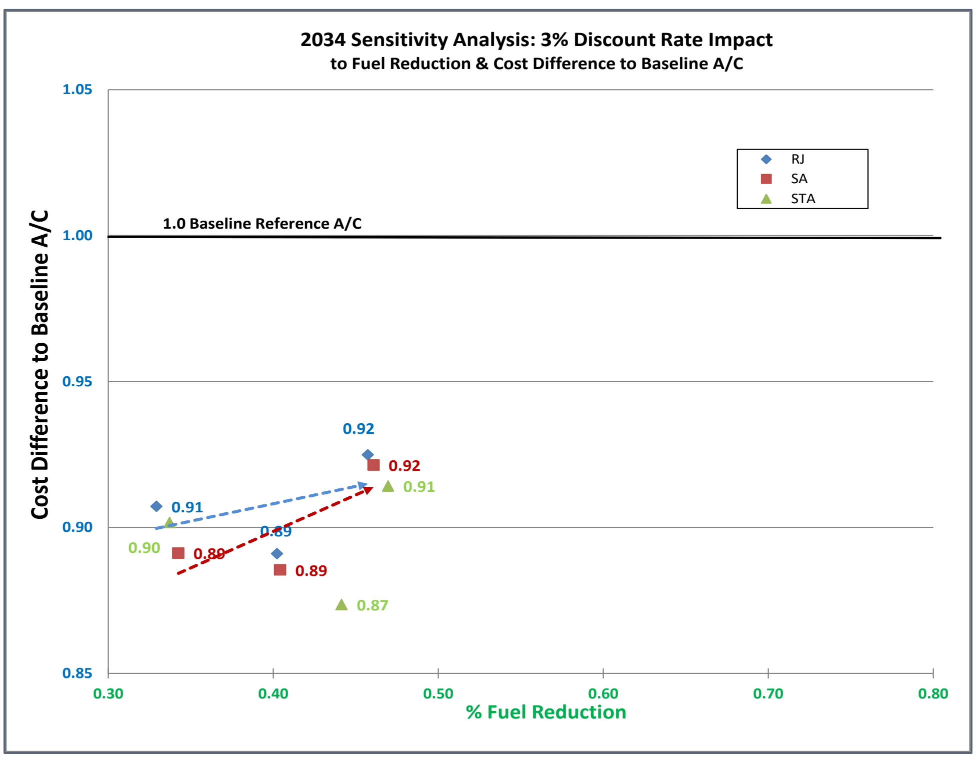


FIGURE P-20 – DISCOUNT RATE SENSITIVITY ANALYSIS – 2034 EIS — 3% DISCOUNT RATE (SA, STA, AND RJ)

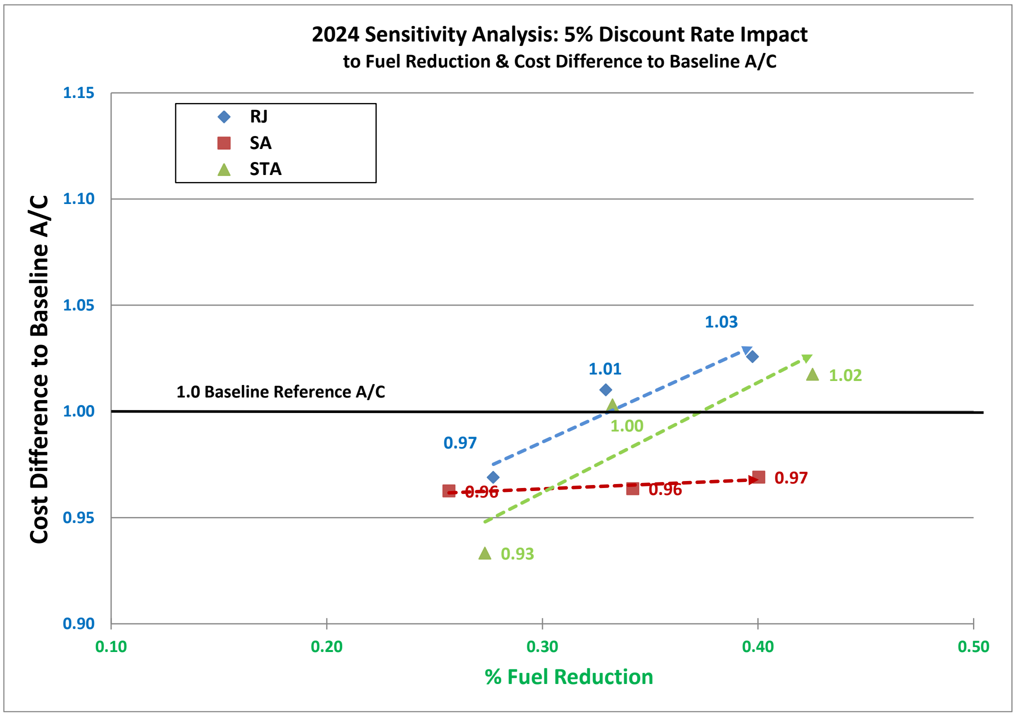


FIGURE P-21 – DISCOUNT RATE SENSITIVITY ANALYSIS – 2024 EIS—5% DISCOUNT RATE (SA, STA, AND RJ)

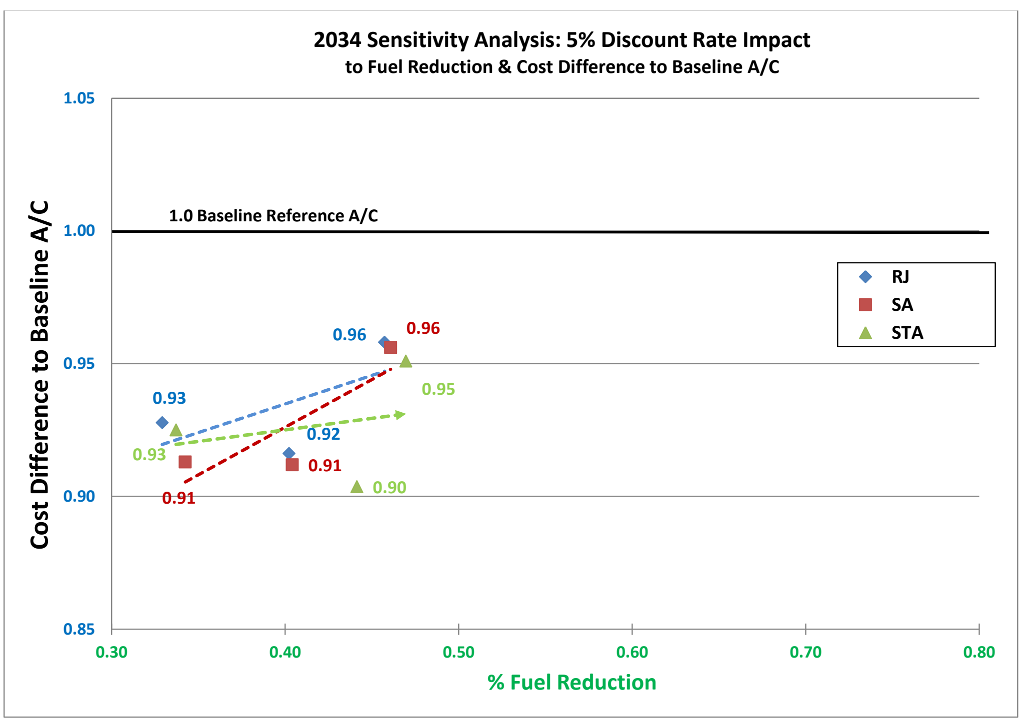


FIGURE P-22 – DISCOUNT RATE SENSITIVITY ANALYSIS – 2034 EIS—5% DISCOUNT RATE (SA, STA, AND RJ)

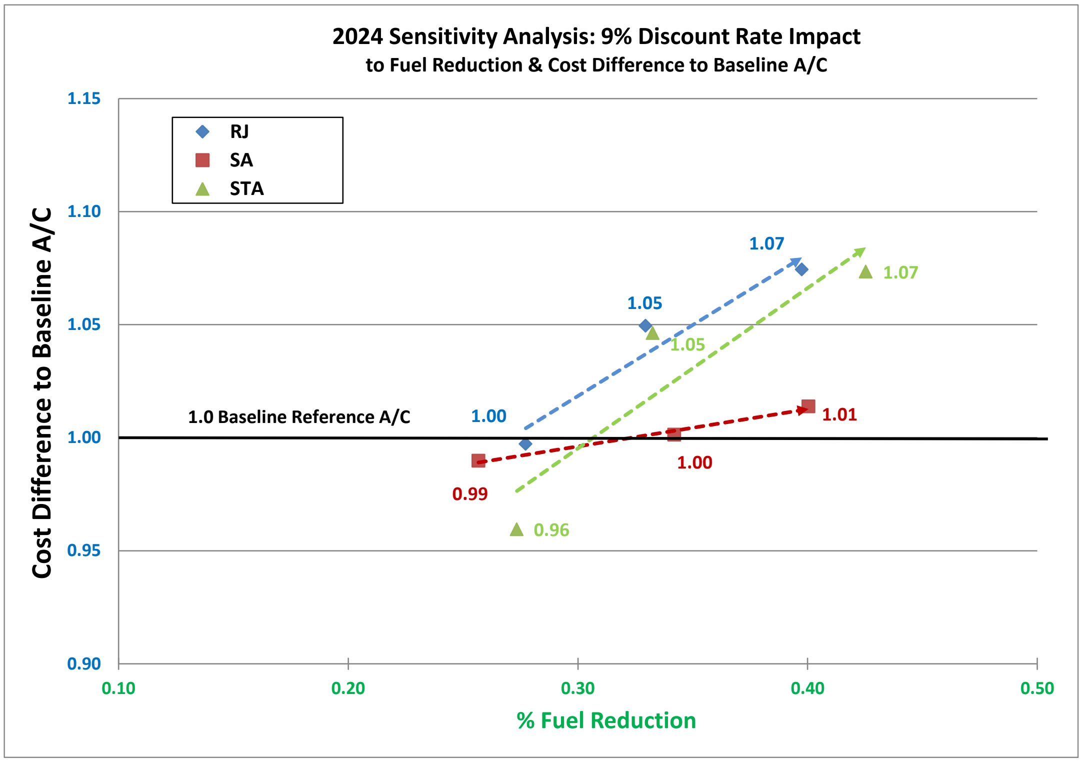


FIGURE P-23 – DISCOUNT RATE SENSITIVITY ANALYSIS – 2024 EIS—9% DISCOUNT RATE (SA, STA, AND RJ)

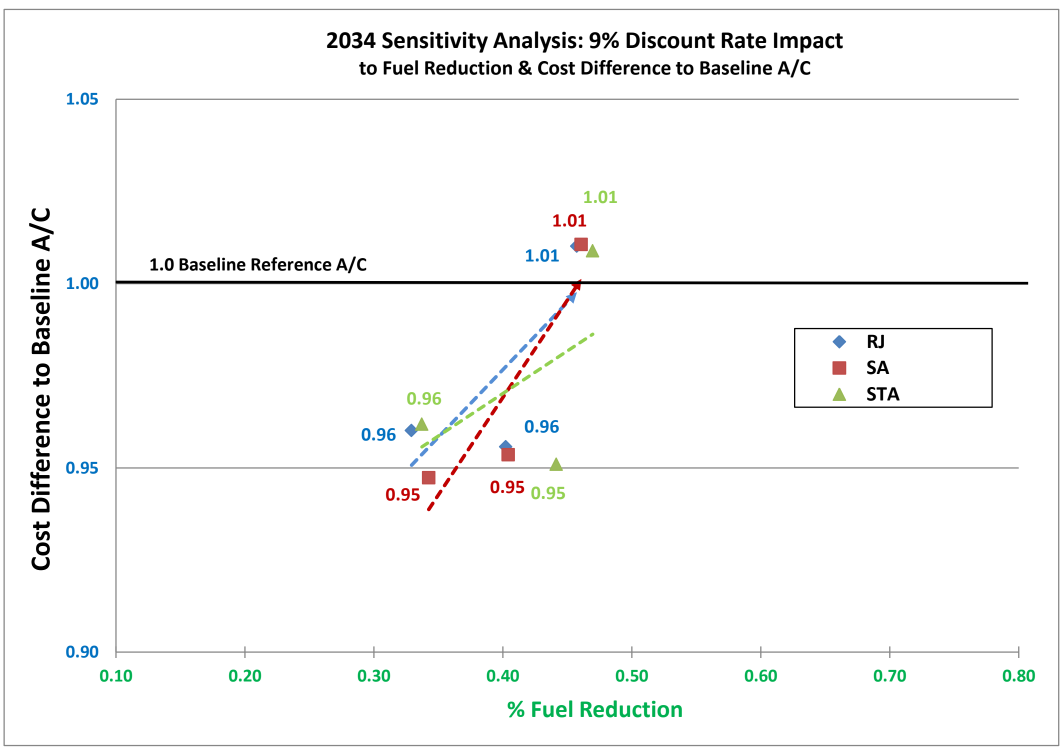


FIGURE P-24 – DISCOUNT RATE SENSITIVITY ANALYSIS – 2034 EIS—9% DISCOUNT RATE (SA, STA, AND RJ)

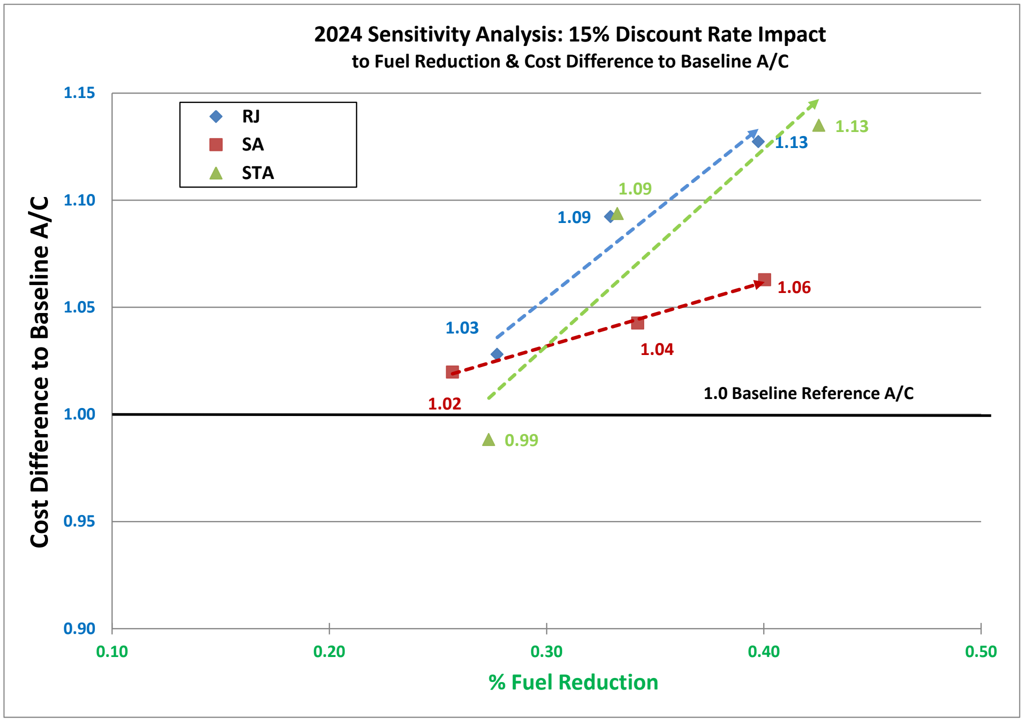


FIGURE P-25 – DISCOUNT RATE SENSITIVITY ANALYSIS – 2024 EIS—15% DISCOUNT RATE (SA, STA, AND RJ)

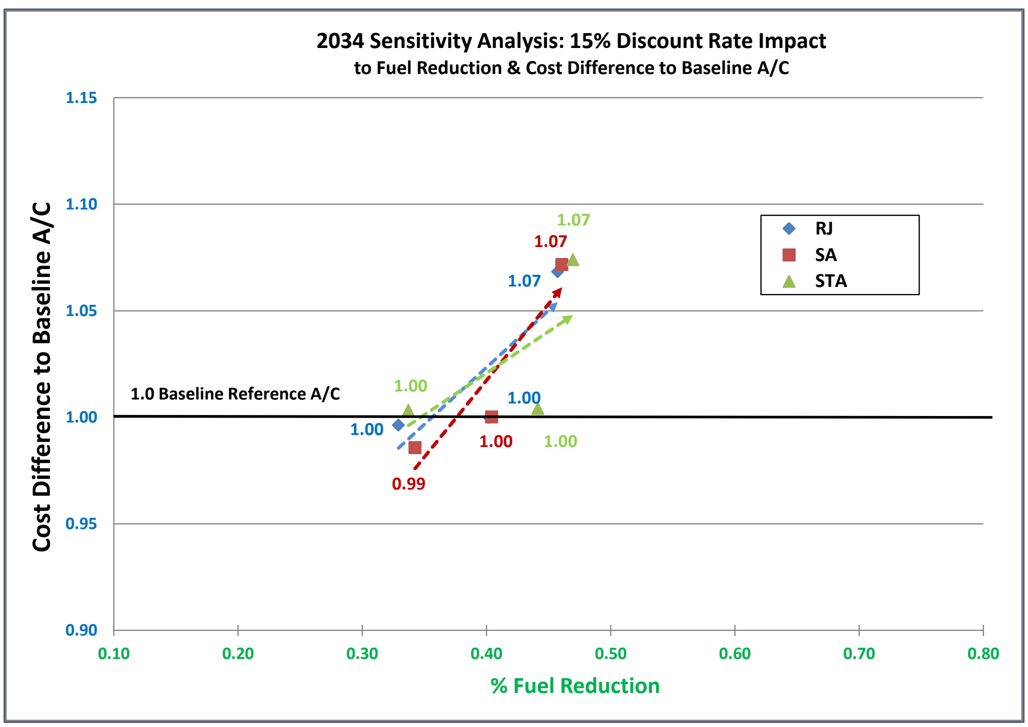


FIGURE P-26 – DISCOUNT RATE SENSITIVITY ANALYSIS – 2034 EIS—15% DISCOUNT RATE (SA, STA, AND RJ)

Figure P-27 and Figure P-28 displays a summary of the various discount rate scenarios. The charts show a weighted composite for each aircraft technology deployment scenario (i.e., Evolutionary, Moderate, and Aggressive) of the cost difference to the baseline aircraft for each discount rate analyzed in the sensitivity analysis. This represents a composite cost to fuel-burn reduction point across all aircraft configurations in the study. From these data points, trend lines were developed to identify the point where there is no net change in operators TOC. By viewing the trend lines one can see how the various discount rates can have an effect on the level of fuel-burn reduction.

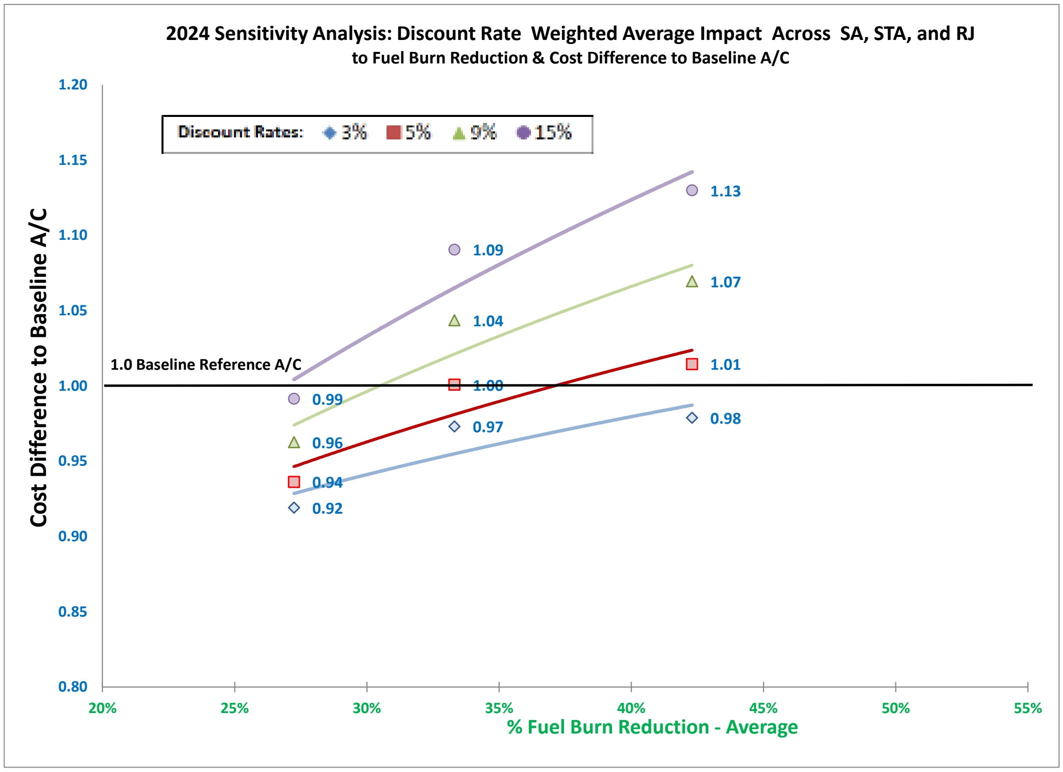


FIGURE P-27 – DISCOUNT RATE SENSITIVITY ANALYSIS-2024 EIS—WEIGHTED AVERAGE

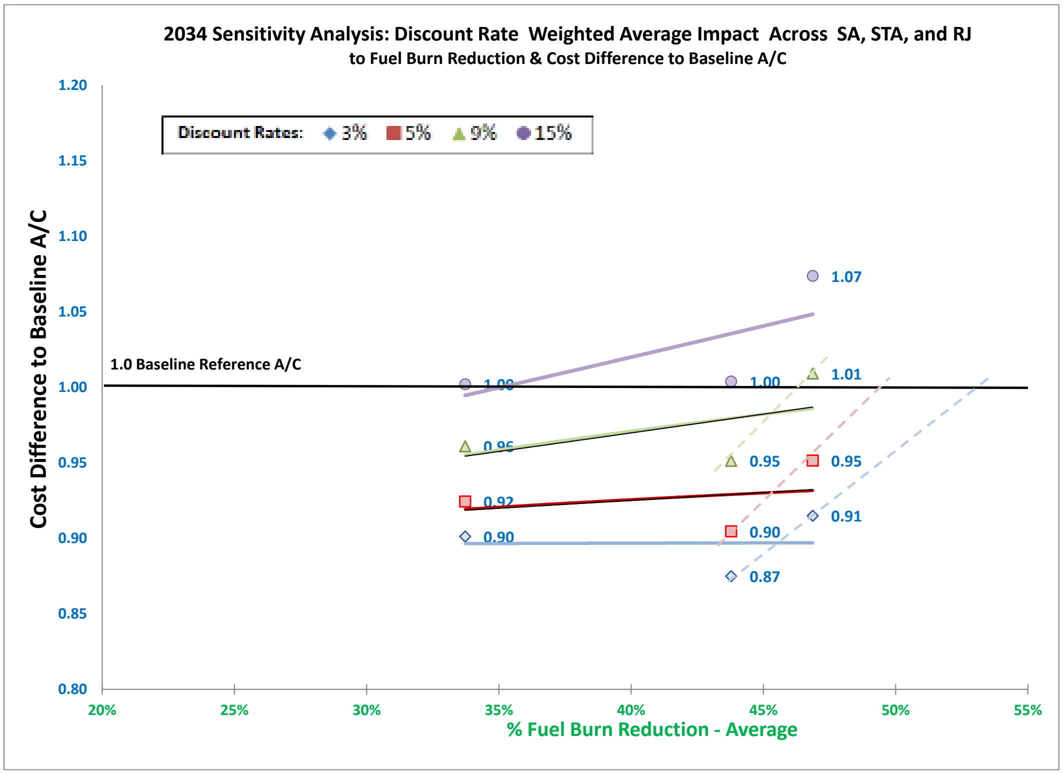


FIGURE P-28 – DISCOUNT RATE SENSITIVITY ANALYSIS-2034 EIS—WEIGHTED AVERAGE