Cost and Benefit Changes from May 2001Safe Flight 21Pre IA CBA In Support of an ADS-B Link Decision

Prepared by ASD-400 with support from MCR Federal Inc.

October 19, 2001

Model Changes

- *Overview*
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  - *Certification Costs*
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Overview

Background

- In May 2001 the FAA published the Safe Flight 21 Pre-Investment Analysis Report
  - Documented Rough Order of Magnitude (ROM) costs and benefits for implementing Safe Flight 21
    - Based on high-level assumptions developed by the cost benefit group prior to the link assessment or a detailed mission analysis
  - Documented a framework of cost and benefit estimating mechanisms for evaluating SF21 as we learn more on costs, demand, and expected performance of ADS-B

Current Objective

- To gain better insight into the expected unit costs and associated equipage for ADS-B under a range of link scenarios
- To apply new findings on ADS-B link costs and expected performance to the cost and benefit models developed for Safe Flight 21
- To document findings and develop and addendum to the May 2001 report documenting modifications to cost and benefit models

Link Scenarios Evaluated

Link Scenarios

- Unit costs developed for following link scenarios:
  - A. 1090 ES
  - B. UAT
  - C. VDLM4
  - D. 1090 & UAT (GA High & All Air Carrier)
  - E. 1090 & VDLM4 (GA High & All Air Carrier)
  - F. UAT & 1090 Transmit only (GA only)
    1090 & UAT Transmit only (Air Carrier only)
  - G. UAT & 1090 Receive only (GA only)
    1090 & UAT Receive only (Air Carrier only)

Link Scenario Table

Scenarios	Low/Mid GA - Basic Avionics	High GA & Air Taxi Advanced	Air Transport
A	1090 ES		
B	UAT		
C	VDLM4		
D	UAT	1090 ES & UAT	
E	1090 ES	1090 ES & VDLM4	
F	UAT & 1090 ES TX		1090 & UAT TX
G	UAT & 1090 RX		1090 & UAT RX

Justification for Link Scenario Selection

- Scenarios provide point estimates of costs and benefits across a range of possible architectures and implementations
- Specific scenarios were developed to
  - Enable an effective and timely update to the cost/benefit analysis
  - Reflect the widest cross-section of possible ADS-B architectures while limiting the number of analyses required
- Scenario definition does not limit the scope of the equipage alternatives considered for the final link recommendation
  - The final recommendation may incorporate all or parts of any of these scenarios
- Scenarios are end-state and do not address possible transition steps

Overriding Assumptions

- Designed for minimum avionics equipage and full interoperability with equipped aircraft independent of ground infrastructure
- Low-end GA equipage rates are the most cost sensitive
  - The need for more than one full transmit/receive-capable link system would impact equipage
- All transport aircraft (with ≥20 seats) are equipped with TCAS or TCAS II
- Scenarios must support (to the extent possible) all SF21 applications
- Included each single-link case across all user segments
- Full dual-link scenarios considered in light of potential exclusive single link technology in certain areas of the world

Overriding Assumptions (Cont.)

- Based on feedback from the Industry meeting we assume
  - UAT is generally preferred by GA owners (low-end & perhaps to a somewhat less extent by high-end GA)
  - 1090 ES is generally preferred by transport aircraft owners/operators
- Limited dual-link scenarios considered
  - Preferred link equipage, and minimum required of other link
- Each dual-link scenario contains 1090 ES as one of the links
  - 1090 has current international acceptance/standards/spectrum, and interest by a significant number of users and vendors
  - Full dual-link equipage limited to transport and high-end GA
  - VDL Mode 4 cannot operate in a transmit-only mode limiting the possible dual-link scenarios with VDL Mode 4

Avionics Cost Estimates

Avionics Cost Category Changes

- General Aviation (GA) and Air Taxi (AT) aircraft divided into two categories:
  - Low/Mid GA -- Basic Avionics
  - High GA and Air Taxi -- Advanced Avionics
- High GA and Air Taxi also include some commuter aircraft
- Air Carrier divided into three groups that will retrofit:
  - Classic aircraft without Primary Flight Display (Non-PFD)
    - Example: 727-100/200; 737-200/300; DC-9 Series
  - Neo-classic aircraft with Primary Flight Display
    - Example: 737-400; A-300; Fokker F-100; MD-80 Series & early MD-90 Series; early 757/767 Series
  - Modern & integrated aircraft with Primary Flight Display
    - Example: 737 NG; 757/767 NG; 777 Series; 717 & late MD-90 Series
- Air Carrier costs developed for forward fit of new modern & integrated aircraft

Avionics Configuration

- Introduced consistency of terminology for avionics configuration
- The avionics configuration consists of:
  - Application processor (referred to as LDPU in May 2001 CBA)
  - Display (referred to as CDTI or MFD in May 2001 CBA)
  - GPS
  - Link System (includes transponder)
  - Installation (Parts and Labor)

Justification for Cost Category Changes

- The May 2001 analysis assumed that the driver was (Non-TCAS, Existing TCAS, Hybrid TCAS) whereas, we now know that this is not the key differentiator of cost
  - The main cost driver for air carriers is the requirement for display upgrade and or integration of ADS-B with aircraft software
  - This is best differentiated by looking at aircraft by the groupings of classic, neo-classic, and modern/integrated
- GA and Air Taxi, depending on several influence factors (age of aircraft, current avionics mix, revenue generation, etc.) will either equip with basic or advanced avionics

Unit Cost Assumptions/Methodology

- For the retrofit cases
  - Unit costs were derived from averaged vendor quotes and
  - Actual display costs by group (Non-PFD, Neo-Classic (PFD), Modern/Integrated (PFD)) were used
  - Aircraft certification costs developed on a per type basis
- Applied a rule of thumb for forward fit costs based on the retrofit estimates and discussions with Boeing
  - No cost for GPS
  - 85% of the display cost
  - Full cost for the link system
  - 25% of the installation costs
  - Aircraft certification will be required

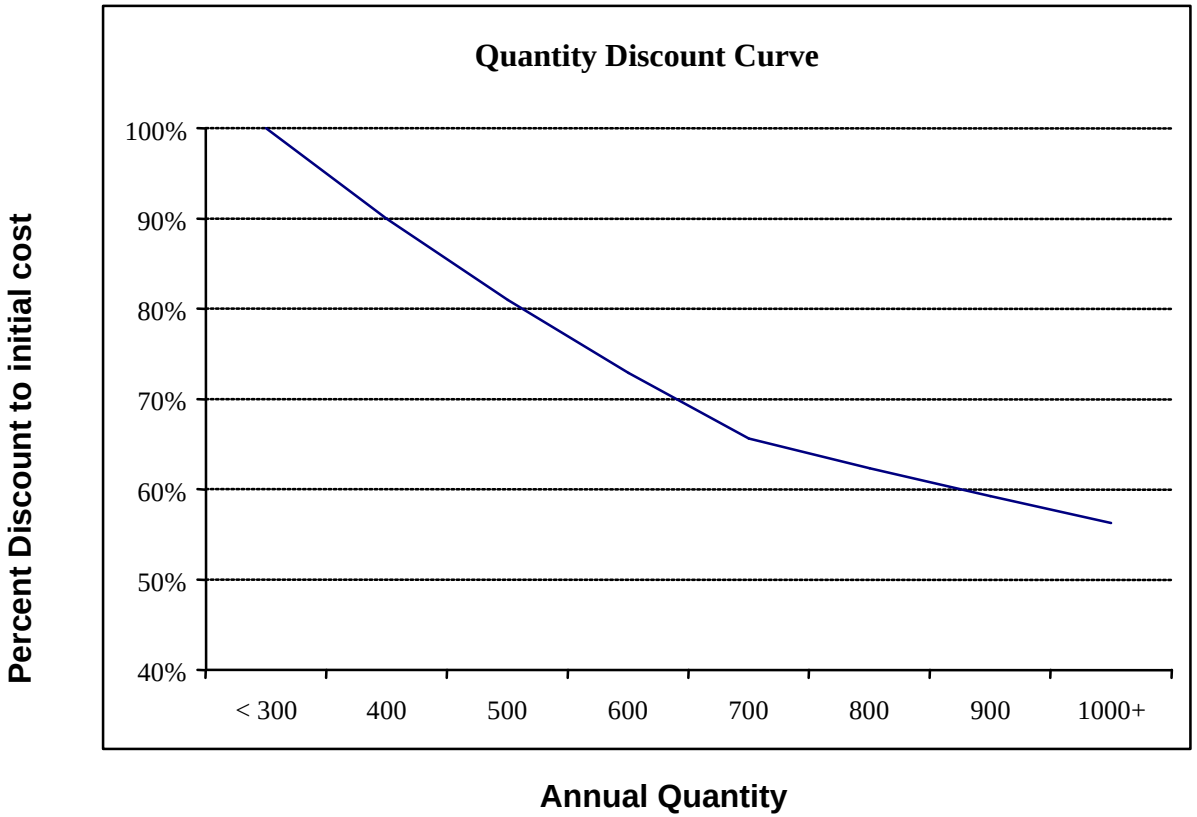
Total Unit Point Estimates

TOTAL UNIT COSTS BY AIRCRAFT CATEGORY BY LINK SCENARIO ($)						
			Air Carriers Retro-fit			AC Forward Fit
Scenario	Low/Mid GA - Basic Avionics	High GA & Air Taxi Advanced	Non-PFD (Classic)	PFD (Neo-Classic)	PFD (Mod/Integ)	PFD (Mod/Integ)
A	1090 ES	1090 ES	1090 ES	1090 ES	1090 ES	1090 ES
	14,815	56,844	168,200	501,367	294,700	184,942
B	UAT	UAT	UAT	UAT	UAT	UAT
	12,243	53,866	165,620	498,787	292,120	187,362
C	VDLM4	VDLM4	VDLM4	VDLM4	VDLM4	VDLM4
	19,440	67,566	268,160	552,035	365,660	225,773
D	UAT	1090 ES & UAT	1090 ES & UAT	1090 ES & UAT	1090 ES & UAT	1090 ES & UAT
	12,243	70,470	186,268	519,435	312,768	199,744
E	1090 ES	1090 ES & VDLM4	1090 ES & VDLM4	1090 ES & VDLM4	1090 ES & VDLM4	1090 ES & VDLM4
	14,815	97,850	393,493	664,868	465,993	261,206
F	UAT & 1090 ES TX	UAT & 1090 ES TX	1090 ES & UAT TX	1090 ES & UAT TX	1090 ES & UAT TX	1090 ES & UAT TX
	17,836	66,800	181,268	514,435	307,768	194,744
G	UAT & 1090 ES RX	UAT & 1090 ES RX	1090 ES & UAT RX	1090 ES & UAT RX	1090 ES & UAT RX	1090 ES & UAT RX
	17,359	65,881	181,268	514,435	307,768	194,744

Note: Quantity discount curves will apply to GA & Air Taxi Basic Avionics costs.

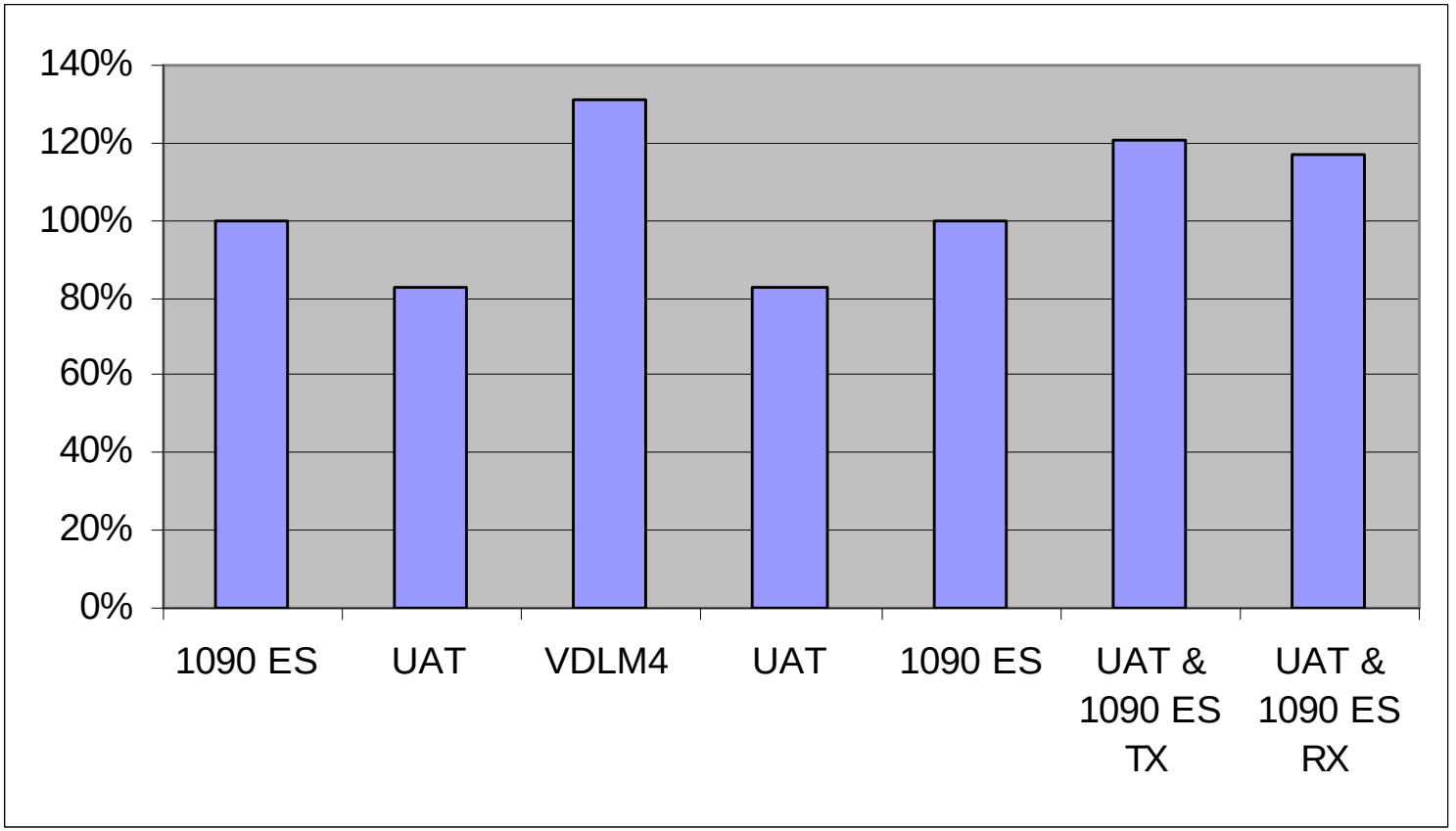
Low/Mid GA - Basic Quantity Discount Curve

- Quantity discount applied to vendor quotes for PME costs
  - 90% curve for 300 to 700 units and 95% curve for 700 to 1000 units
  - User demand assumed to be equally divided between 3 suppliers



Low/Mid GA - Basic Avionics

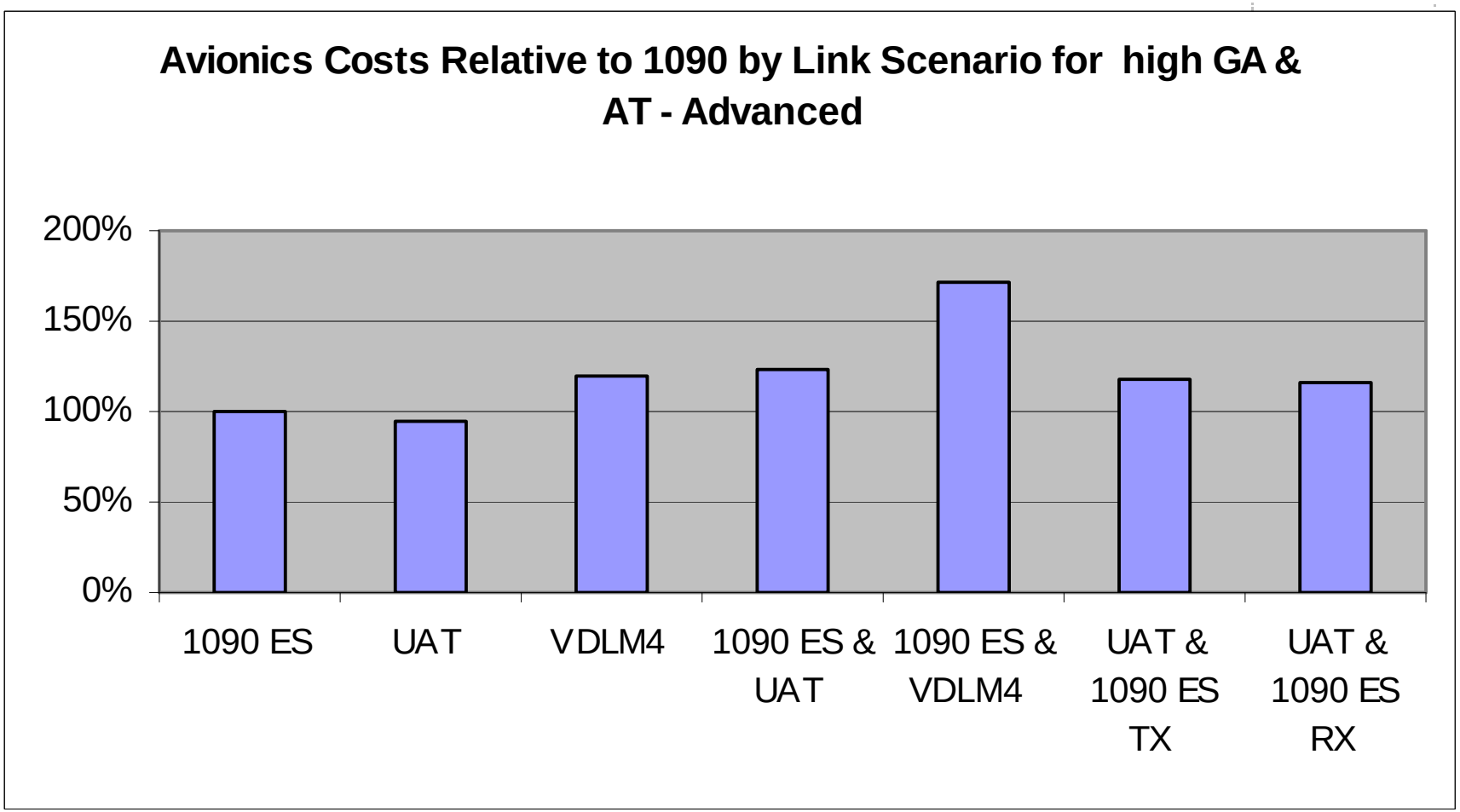
Avionics Costs Relative to 1090 by Link Scenarios for Low/Mid GA - Basic Avionics



Summary of Avionics Cost Findings: Low/Mid GA -- Basic Avionics Aircraft

- UAT single link is ~17% less expensive than 1090 single link
- VDLM4 single link is ~31% more expensive than 1090 single link
- The two dual link scenarios considered in this category, UAT & 1090 ES TX and UAT & 1090 ES RX, are approximately 20% and 17% respectively more expensive than 1090 single link
- Note: If 1090 and UAT antennas are shared, the cost could potentially be reduced by 10% for Scenarios F and G

High GA & Air Taxi -- Advanced Avionics

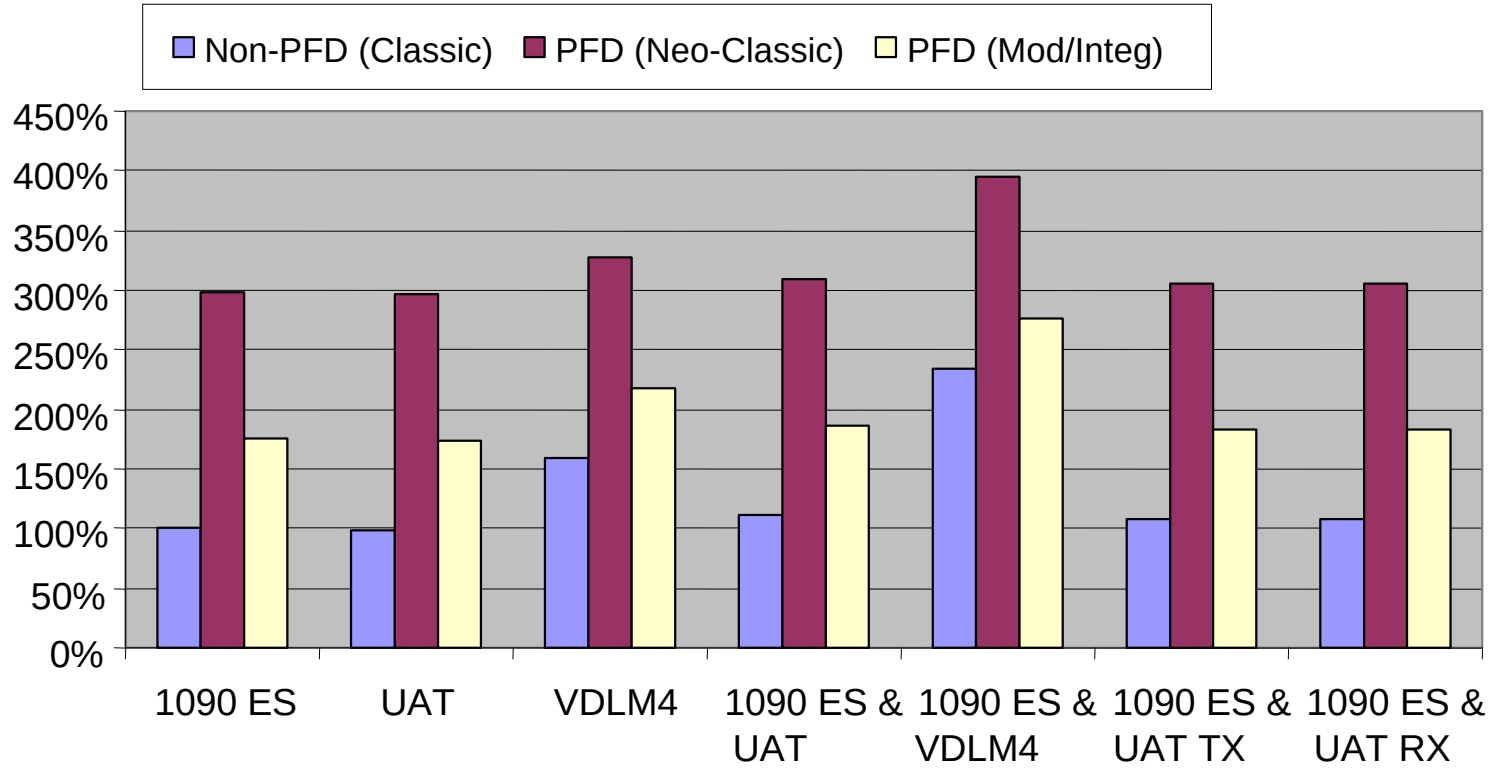


Summary of Avionics Cost Findings: High GA & Air Taxi -- Advanced Avionics

- UAT single link is ~5% less expensive than 1090 single link
- VDLM4 single link is ~19% more expensive than 1090 single link
- 1090 & UAT dual link (Scenario D) is ~24% more expensive than 1090 single link

Air Transport: Retro-fit

Retrofit Avionics Costs Relative to 1090 for Classic Aircraft by Aircraft Class



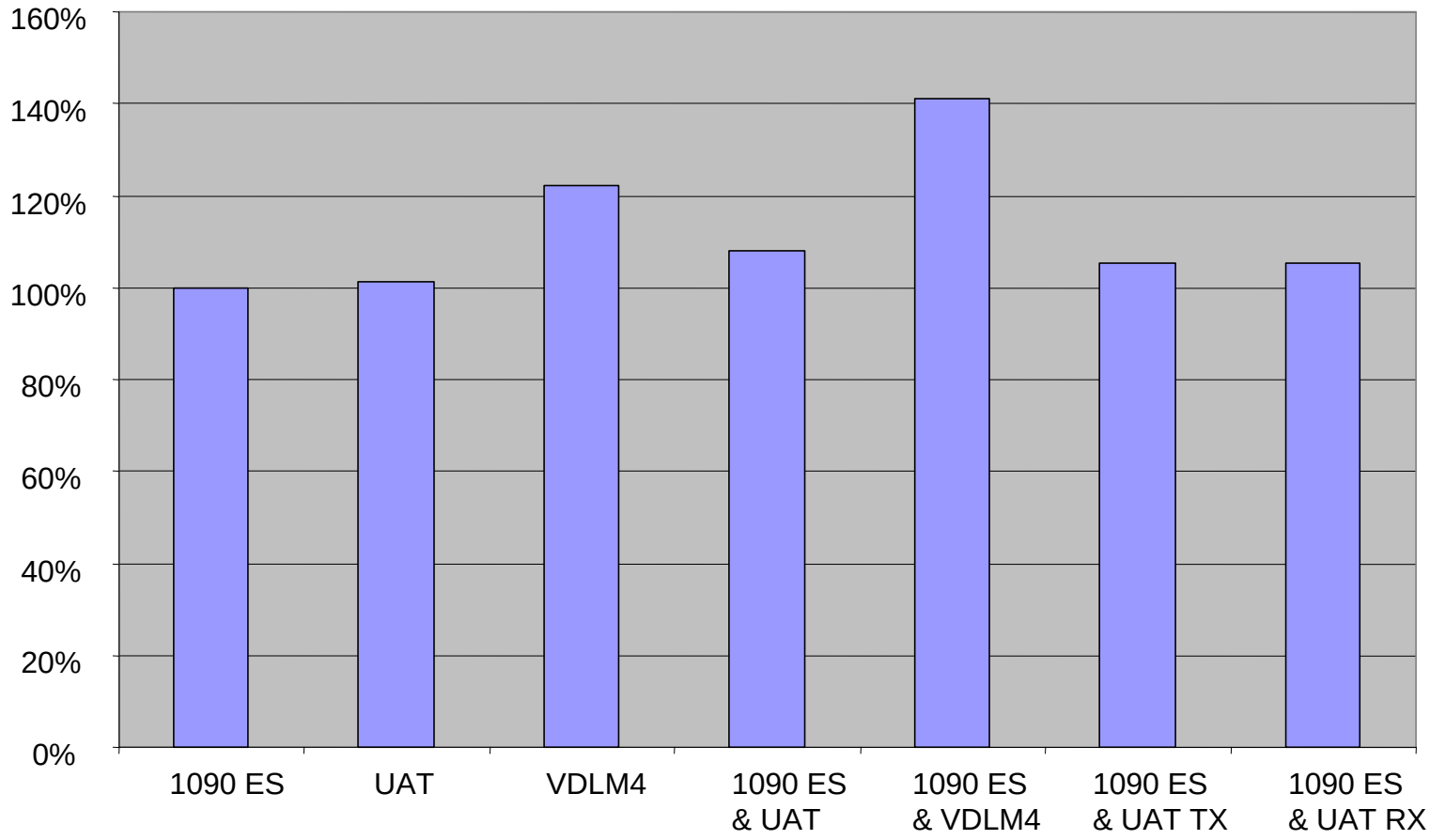
Note: Equipage assumptions are only for a small portion of classics & neo-classics to retrofit with equipment.

Summary of Avionics Cost Findings: Air Carrier Aircraft

- 1090 and UAT single links are nearly cost equivalent for Classic, Neo-Classic and Modern/Integrated aircraft
- VDLM4 compared to 1090 single link:
  - ~59% more expensive for Classic aircraft
  - ~12% more expensive for Neo-Classic aircraft
  - ~24% more expensive for Modern/Integrated aircraft
- 1090/UAT dual link (Scenario D) compared to 1090 single link:
  - ~11% more expensive for Classic aircraft
  - ~4% more expensive for Neo-Classic aircraft
  - ~6% more expensive for Modern/Integrated aircraft

Air Transport: Forward Fit

Forward Fit Avionics Costs Relative to 1090 for Modern/Integrated Air Carriers



Certification Changes

- There are two types of certification costs that have to be accounted for:
  - Equipment certification which refers to certification of the avionics box
    - Included in the avionics costs
  - Aircraft type certification which refers to any modifications to the aircraft type certificate
    - Aircraft type certification costs were developed based on data collected from vendors
- Certification costs for forward fit aircraft are treated in the same manner
  - Separate aircraft type certification will be needed

Unit Certification Costs

Certification Costs Per Aircraft Type (in Millions)					
		Retro-fit			Forward Fit
Scenario	High GA & Air Taxi Advanced	Non-PFD (Classic)	PFD (Neo)	PFD (Mod/Integ)	PFD (Mod/Integ)
A	1090 ES	1090 ES	1090 ES	1090 ES	1090 ES
	0.500	1.000	1.500	2.000	2.000
B	UAT	UAT	UAT	UAT	UAT
	0.5000	1.0000	1.5000	2.0000	2.0000
C	VDLM4	VDLM4	VDLM4	VDLM4	VDLM4
	0.663	1.325	1.988	2.650	2.650
D	1090 ES & UAT	1090 ES & UAT	1090 ES & UAT	1090 ES & UAT	1090 ES & UAT
	0.663	1.325	1.988	2.650	2.650
E	1090 ES & VDLM4	1090 ES & VDLM4	1090 ES & VDLM4	1090 ES & VDLM4	1090 ES & VDLM4
	0.663	1.325	1.988	2.650	2.650
F	UAT & 1090 ES TX	1090 ES & UAT TX	1090 ES & UAT TX	1090 ES & UAT TX	1090 ES & UAT TX
	0.663	1.325	1.988	2.650	2.650
G	UAT & 1090 ES RX	1090 ES & UAT RX	1090 ES & UAT RX	1090 ES & UAT RX	1090 ES & UAT RX
	0.663	1.325	1.988	2.650	2.650

Total Certification Costs by Scenario

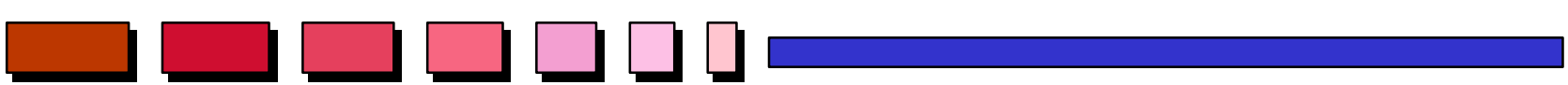
Total Certification Costs (In Millions)					
		Retro-fit			Forward Fit
Scenario	High GA & Air Taxi Advanced	Non-PFD (Classic)	PFD (Neo)	PFD (Mod/Integ)	PFD (Mod/Integ)
Aircraft Type	16	8	9	13	13
A	1090 ES	1090 ES	1090 ES	1090 ES	1090 ES
	8.000	8.000	13.500	26.000	26.000
B	UAT	UAT	UAT	UAT	UAT
	8.0000	8.0000	13.5000	26.0000	26.0000
C	VDLM4	VDLM4	VDLM4	VDLM4	VDLM4
	10.600	10.600	17.888	34.450	34.450
D	1090 ES & UAT	1090 ES & UAT	1090 ES & UAT	1090 ES & UAT	1090 ES & UAT
	10.600	10.600	17.888	34.450	34.450
E	1090 ES & VDLM4	1090 ES & VDLM4	1090 ES & VDLM4	1090 ES & VDLM4	1090 ES & VDLM4
	10.600	10.600	17.888	34.450	34.450
F	UAT & 1090 ES TX	1090 ES & UAT TX	1090 ES & UAT TX	1090 ES & UAT TX	1090 ES & UAT TX
	10.600	10.600	17.888	34.450	34.450
G	UAT & 1090 ES RX	1090 ES & UAT RX	1090 ES & UAT RX	1090 ES & UAT RX	1090 ES & UAT RX
	10.600	10.600	17.888	34.450	34.450
* Certification costs for GA & Air Taxi Basic Avionics are included in system costs.					

Ground Infrastructure Changes

Changes to CBA Cost Assumptions

- Additional updates
  - F&E
    - Airport installation costs increased based on latest ASDE-X inputs
    - Vehicle ADS-B equipage increased based on revised quantity assumptions
  - O&M
    - Costs increased due to the inclusion of maintenance actions for additional system components: reference transponders, cabinets, displays - based on latest ASDE-X inputs
  - Base Year changed from FY00 to FY01

Ground Stations Unit Costs



Transmit/Receive		
Equipage Scenario	T/R without Redundancy $K	T/R with Redundancy $K
A-1090	$89.5	$154.5
B-UAT	$85.0	$150.0
C-VDLM4	$115.0	$225.0
D-1090/UAT	$119.5	$184.5
E-1090/VDLM4	$154.5	$264.5
F-1090/UAT- Tx only	$119.5	$184.5
G-1090/UAT- Rx only	$119.5	$184.5

Receive Only		
Equipage Scenario	Receive-Only without Redundancy $K	Receive-Only with Redundancy $K
A-1090	$54.5	$119.5
B-UAT	$50.0	$115.0
C-VDLM4	$80.0	$180.0
D-1090/UAT	$84.5	$149.5
E-1090/VDLM4	$115.0	$225.0
F-1090/UAT- Tx only	$84.5	$149.5
G-1090/UAT- Rx only	$84.5	$149.5

Units per Category by Scenario

Scenario A	Sites	ROs	Unit Cost $K	Total Cost $K	Sites	RTs	Unit Cost $K	Total Cost $K	Sites	REFTRAN	Unit Cost $K	Total Cost $K
Surface				$0.0				$0.0				$0.0
Initial Buy	119	3	$54.5	$19,456.5	119	4	$89.5	$42,602.0	119	1	$60.0	$7,140.0
Remainder Buy				$0.0	268	2	$154.5	$82,812.0				$0.0
ASDE-X/ASDE-3 sites	60	9	$0.0	$0.0	60	9	$0.0	$0.0	60	2	$0.0	$0.0
Enroute				$0.0	100	1	$154.5	$15,450.0				$0.0
				$19,456.5				$140,864.0				$7,140.0

Scenario B	Sites	ROs	Unit Cost $K	Total Cost $K	Sites	RTs	Unit Cost $K	Total Cost $K	Sites	REFTRAN	Unit Cost $K	Total Cost $K
Surface				$0.0				$0.0				$0.0
Initial Buy	119	3	$50.0	$17,850.0	119	4	$85.0	$40,460.0	119	1	$60.0	$7,140.0
Remainder Buy				$0.0	268	2	$150.0	$80,400.0				$0.0
ASDE-X/ASDE-3 sites	60	9	$30.0	$16,200.0	60	9	$30.0	$16,200.0	60	2	$30.0	$3,600.0
Enroute				$0.0	100	1	$150.0	$15,000.0				$0.0
				$34,050.0				$152,060.0				$10,740.0

Scenario C	Sites	ROs	Unit Cost $K	Total Cost $K	Sites	RTs	Unit Cost	Total Cost $K	Sites	REFTRAN	Unit Cost $K	Total Cost $K
Surface				$0.0				$0.0				$0.0
Initial Buy	119	3	$80.0	$28,560.0	119	4	$115.0	$54,740.0	119	1	$60.0	$7,140.0
Remainder Buy				$0.0	268	2	$225.0	$120,600.0				$0.0
ASDE-X/ASDE-3 sites	60	9	$30.0	$16,200.0	60	9	$30.0	$16,200.0	60	2	$30.0	$3,600.0
Enroute				$0.0	100	1	$225.0	$22,500.0				$0.0
				$44,760.0				$214,040.0				$10,740.0

Scenario D,F,G	Sites	ROs	Unit Cost $K	Total Cost $K	Sites	RTs	Unit Cost $K	Total Cost $K	Sites	REFTRAN	Unit Cost $K	Total Cost $K
Surface				$0.0				$0.0				$0.0
Initial Buy	119	3	$84.5	$30,166.5	119	4	$119.5	$56,882.0	119	1	$60.0	$7,140.0
Remainder Buy				$0.0	268	2	$184.5	$98,892.0				$0.0
ASDE-X/ASDE-3 sites	60	9	$30.0	$16,200.0	60	9	$30.0	$16,200.0	60	2	$30.0	$3,600.0
Enroute				$0.0	100	1	$184.5	$18,450.0				$0.0
				$46,366.5				$190,424.0				$10,740.0

Scenario E	Sites	ROs	Unit Cost $K	Total Cost $K	Sites	RTs	Unit Cost $K	Total Cost $K	Sites	REFTRAN	Unit Cost $K	Total Cost $K
Surface				$0.0				$0.0				$0.0
Initial Buy	119	3	$115.0	$41,055.0	119	4	$154.5	$73,542.0	119	1	$60.0	$7,140.0
Remainder Buy				$0.0	268	2	$264.5	$141,772.0				$0.0
ASDE-X/ASDE-3 sites	60	9	$30.0	$16,200.0	60	9	$30.0	$16,200.0	60	2	$30.0	$3,600.0
Enroute				$0.0	100	1	$264.5	$26,450.0				$0.0
				$57,255.0				$257,964.0				$10,740.0

ASDE-X/ASDE-3 ground stations purchased under another program

PME costs based on revised inputs from contractor

See May 2001 CBA report for documentation on the bases of estimate for the whole WBS.

Aircraft Equipage Schedules

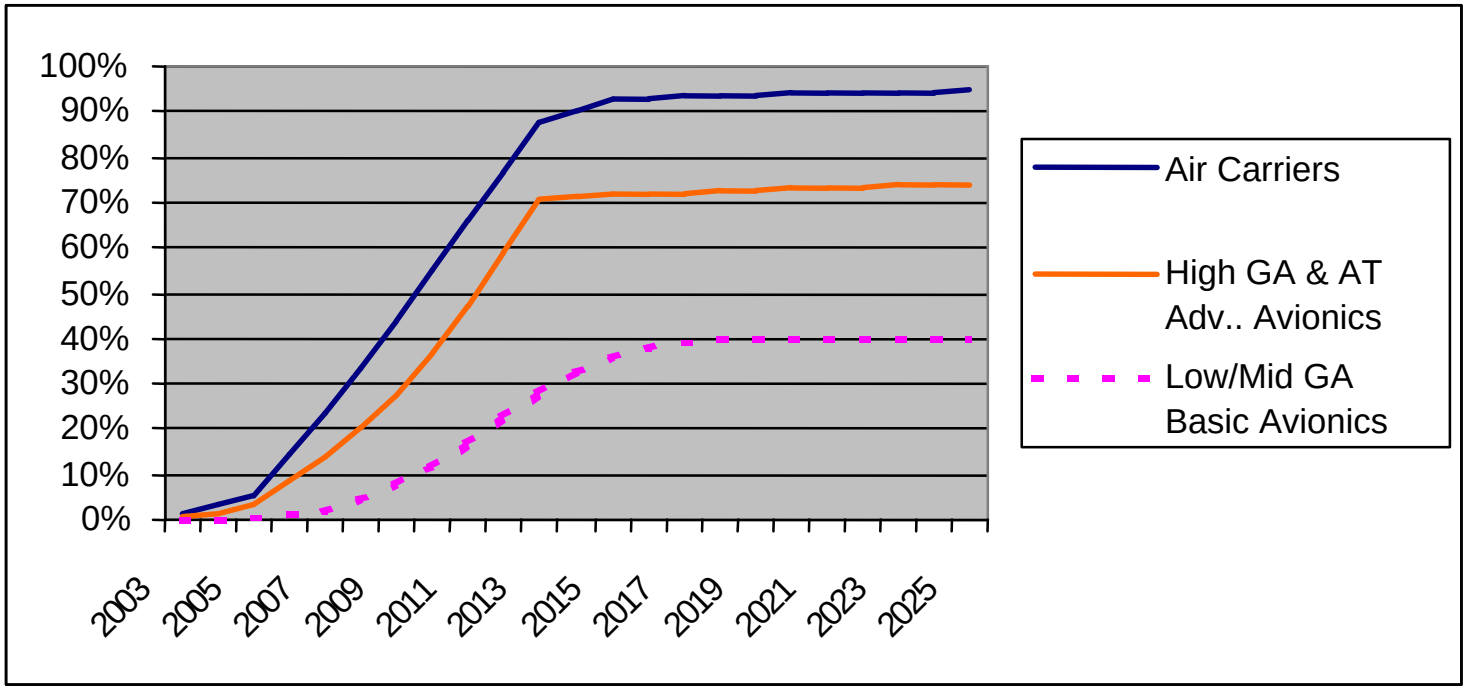
Scenarios A,B,D,E,F,G

	FY03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
forward fit-mod/integ	0	0	0	537	548	559	571	584	529	538	547	556	565	305	314	323	333	342	297	305	312	320	328	8712
retro classic	7	7	7	7	7	7	7	7	7	7	7	0	0	0	0	0	0	0	0	0	0	0	0	82
retro -neo classic	55	55	55	55	55	55	55	55	55	55	55	0	0	0	0	0	0	0	0	0	0	0	0	605
retro -modern/integ	37	56	112	131	187	225	412	524	599	599	674	0	0	0	0	0	0	0	0	0	0	0	0	3556
High GA & AT - Advanced	60	121	181	660	729	919	1049	1360	1624	1873	2062	319	327	281	287	293	299	306	268	272	277	282	287	14139
Low/Mid GA - Basic	102	208	528	1182	2345	4112	6376	8745	10624	11421	10882	9210	6951	4644	2857	1661	977	641	409	411	413	415	417	85529

Scenario C

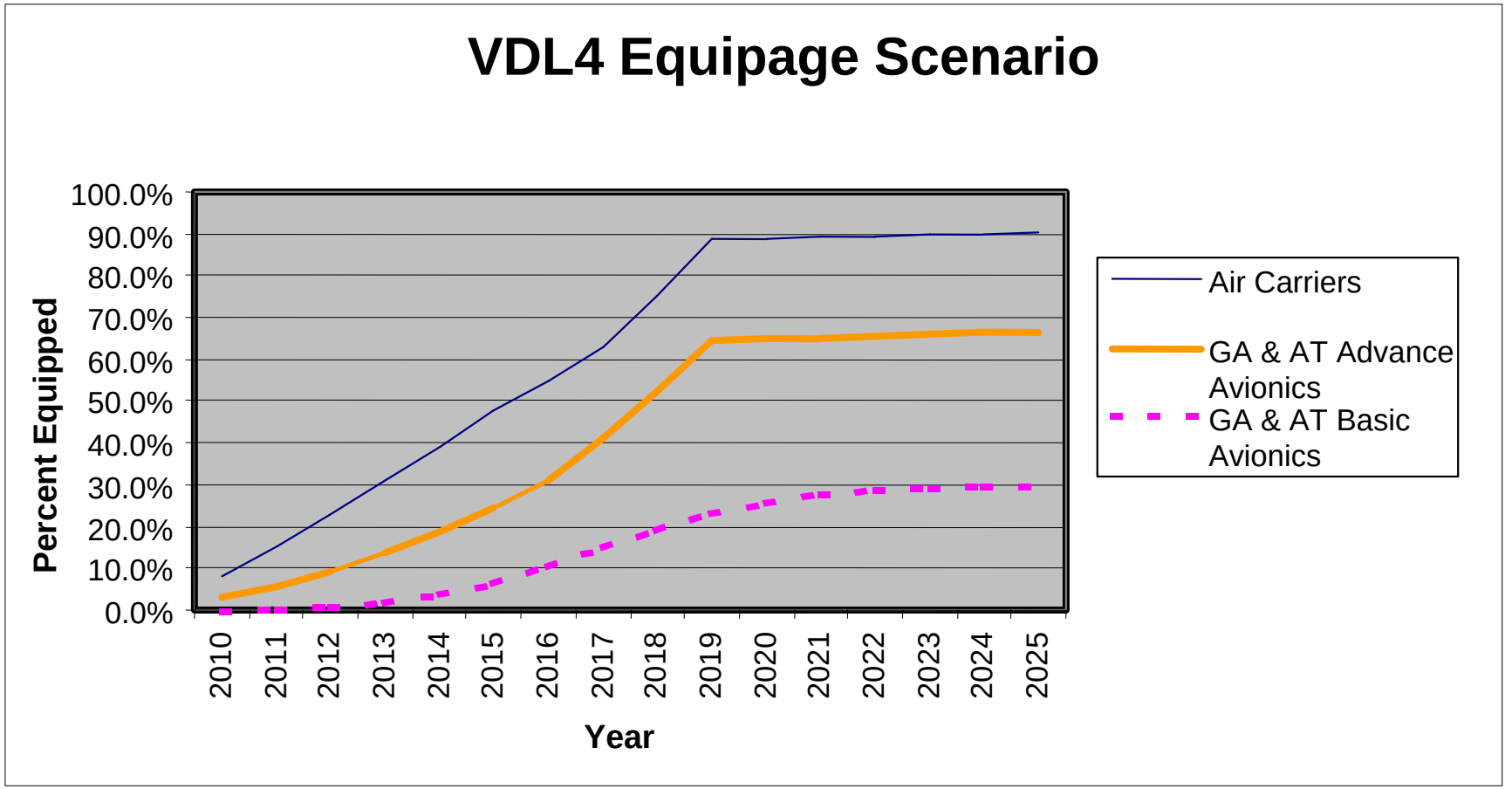
	FY03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total
forward fit-mod/integ	0	0	0	0	0	0	0	584	529	538	547	556	565	305	314	323	333	342	297	305	312	320	328	6497
retro classic	0	0	0	0	0	0	0	7	7	7	7	7	7	7	7	7	7	0	0	0	0	0	0	75
retro -neo classic	0	0	0	0	0	0	0	55	55	55	55	55	55	55	55	55	55	0	0	0	0	0	0	550
retro -modern/integ	0	0	0	0	0	0	0	71	119	179	238	328	417	506	715	1192	1490	0	0	0	0	0	0	5255
High GA & AT - Advanced	0	0	0	0	0	0	0	401	431	507	717	793	1004	1094	1777	2053	2263	306	268	272	277	282	287	12732
Low/Mid GA - Basic	0	0	0	0	0	0	0	256	471	1093	2205	3873	5922	7866	9112	9203	8114	6264	4256	2586	1453	810	502	63987

Equipage Curves for Non-VDL 4 Scenarios



- VDL 4 curves (scenario C) reflect no equipage until 2010 resulting in
  - lower demand for Air Carriers - 90% to equip by 2025
  - lower demand for GA and AT Advanced - 67% to equip by 2025
  - lower demand for GA and AT Basic - 30% to equip by 2025

Equipage Curves for VDL 4 Scenario



Cost Results - Total Costs
Current Year $M

Equipage Scenario	Avionics Costs	Ground Costs	Total Costs
A	$7,910	$2,664	$10,574
B	$7,678	$2,676	$10,355
C	$8,955	$2,920	$11,874
D	$8,289	$2,876	$11,165
E	$10,539	$3,176	$13,715
F	$8,551	$2,876	$11,427
G	$8,502	$2,876	$11,378

- Ground costs are based on estimates for PME, training, spares, logistics support, etc.
- Completed Work Breakdown Structure and Basis of Estimate are documented in the May 2001 SF21 Pre-IA CBA Report

Scenarios	Low/Mid GA Basic	High GA & AT	Air Transport
A	1090 ES		
B	UAT		
C	VDLM4		
D	UAT	1090 ES & UAT	
E	1090 ES	1090 ES & VDLM4	
F	UAT & 1090 ES TX		1090&UAT TX
G	UAT & 1090 RX		1090&UAT RX

Cost Results - Avionics Costs
Current Year $M

Equipage Scenario	Low/Mid GA - Basic	High GA & AT -Adv	Retro-fit Non-PFD (Classic)	Retro-fit PFD (Mod/Integ)	Retro-fit PFD (Neo)	Forward Fit PFD (Mod/Integ)	Simulator Upgrades	Total Cost $M
A	$2,195	$1,279	$26	$1,469	$409	$2,477	$56	$7,910
B	$2,005	$1,221	$26	$1,457	$407	$2,507	$56	$7,678
C	$1,749	$1,393	$40	$2,937	$459	$2,312	$64	$8,955
D	$2,005	$1,541	$31	$1,561	$427	$2,669	$56	$8,289
E	$2,195	$2,056	$49	$2,240	$530	$3,412	$56	$10,539
F	$2,427	$1,471	$30	$1,537	$424	$2,607	$56	$8,551
G	$2,395	$1,453	$30	$1,537	$424	$2,607	$56	$8,502

Scenarios	Low/Mid GA Basic	High GA & AT	Air Transport
A	1090 ES		
B	UAT		
C	VDLM4		
D	UAT	1090 ES & UAT	
E	1090 ES	1090 ES & VDLM4	
F	UAT & 1090 ES TX		1090&UAT TX
G	UAT & 1090 RX		1090&UAT RX

Cost Results - Ground Costs
Current Year $M

Equipage Scenario	F&E	O&M	Total Cost
A	$1,829	$835	$2,664
B	$1,841	$835	$2,676
C*	$2,083	$837	$2,920
D	$1,969	$907	$2,876
E*	$2,161	$1,015	$3,176
F	$1,969	$907	$2,876
G	$1,969	$907	$2,876

* Telecommunication costs are not fully captured for Scenarios C and E

Benefits Changes

Benefits (Summary)

- Methodology used in quantifying benefits remains the same
- Three input areas have been changed:
  - Determined the effectiveness of each application for all link scenarios
  - Updated equipage curves estates, including start, end dates, and level of equipage, for each link scenario
  - Reviewed and modified equipage curve scenarios
    - Assigned according to whether one or both aircraft need to be equipped with ADS-B and/or transponder to realize benefits
- All other inputs remain the same

Effectiveness of all link scenarios

- Effectiveness of application is defined by expected improvement given technology adoption.
  - See May 2001 CBA report for documentation on effectiveness assumptions by application
- For each applications, determined effectiveness of proposed link and developed an "effectiveness multiplier."
  - Values range from 0% to 100%.
    - 0% means that the proposed link for the aircraft category does not support the application.
    - 100% means that the proposed link for the aircraft category completely supports the application.
    - Intermediate values indicate partial support.

Summary of Effectiveness Multipliers

Applications	A-1090,E-1090/VDL4, F1090(tx only GA)/UAT(tx only AC)*	B-UAT, D-1090/UAT, G-UAT/1090Rx	C-VDL-4
1. Weather and Other Information to the Cockpit			
1.1.1 Initial FIS-B based on today's availability	0.7	1	1
1.1.2 Add products such as NOTAMs, lightning, icing, turbulence, real time SUA, & Volcanic ash	0.4	1	1
2. Cost Effective CFIT Avoidance			
2.1 Low cost terrain situational awareness	1	1	1
2.2 Increased access to terrain constrained low altitude airspace	1	1	1
3. Improved Terminal Ops in Low Visibility			
3.1.1 Enhanced visual approaches (Visual acquisition with existing procedures, ADS-B only	1	1	0.8
3.1.2 Enhanced visual approaches (w/ new procedures - ADS-B only)	1	1	0.8
3.1.3 Enhanced visual approaches (w/ new procedures - ADS-B & TIS-B)	0.8	0.8	0.8
3.2.1 Approach spacing (for visual approaches)	1 / 0.8 **	1 / 0.8 **	0.8 / 0.8 **
3.2.2 Approach spacing (for instrument approaches)	1	1	0.8
3.4 Departure spacing/clearance (VMC in radar)	Not modeled	Not modeled	Not modeled
4. Enhanced See and Avoid			
4.1.1 Enhanced visual acquisition of other traffic for see-and-avoid (using ADS-B only)	1	1	0.8
4.1.2 Enhanced visual acquisition of other traffic for see-and-avoid (ADS-B and TIS-B)	0.8	0.8	0.8
4.2.1 Conflict detection	1	1	0.8
4.2.2 Conflict resolution	1	1	0.8
5. Enhanced En Route Air-to-Air Operations			
5.2.1 Pilot situational awareness beyond visual Range	Not modeled	Not modeled	Not modeled
6. Improved Surface Surveillance & Pilot Navigation			
6.1.1 Runway & final approach occupancy awareness (ADS-B only)	0.9	0.9	0.9
6.1.2 Runway & final approach occupancy awareness (ADS-B & TIS-B)	1	1	1
6.2 Airport surface situational awareness	1	1	1
7. Enhanced Surface Surveillance for Controller			
7.1 Enhance existing surface surveillance with ADS-B	Not modeled	Not modeled	Not modeled
7.2 Surveillance coverage at airports w/out existing surface surveillance	1	1	1
8. ADS-B Surveillance in Non-Radar Airspace			
8.2 Radar-like services with ADS-B	1	1	1
8.3 Tower situational awareness beyond visual range	1	1	1
9. Establish ADS-B Separation Standards	Not modeled	Not modeled	Not modeled

* For Scenarios E and F for enhancement 1, will develop a weighted average value to apply to the effectiveness

** For ADS-B to ADS-B the effectiveness multiplier will be 1 for 1090 and UAT and .8 for VDL 4; ADS-B to non-ADS-B gets a .8

Equipage Curves

- Revised user plans for equipages for different link scenarios
- Time line and levels of equipage are based on feedback received at the two User/Industry meetings
- Updated equipage scenarios (need an updated table 5-5):

Application/Link scenario matrix

Applications / Scenarios	A-1090,E-1090/VDL4, E1090(tx only GA)/UAT(tx only		B-UAT, D-1090/UAT, G-UAT/1090Rx		C-VDL-4	
	Code	Equipage curve	Code	Equipage curve	Code	Equipage curve
1. Weather and Other Information to the Cockpit						
1.1.1 Initial FIS-B based on today's availability	Y	Indep	G	Indep	G	Indep
1.1.2 Add products such as NOTAMs, lightning, icing, turbulence, real time SUA, & Volcanic ash	Y	Indep	G	Indep	G	Indep
2. Cost Effective CFIT Avoidance						
2.1 Low cost terrain situational awareness	G	Indep	G	Indep	G	Indep
2.2 Increased access to terrain constrained low altitude airspace	G	Indep	G	Indep	G	Indep
3. Improved Terminal Ops in Low Visibility						
3.1.1 Enhanced visual approaches (Visual acquisition with existing procedures, ADS-B only	G	Dependent	G	Dependent	Y	Dependent
3.1.2 Enhanced visual approaches (w/ new procedures - ADS-B only)	G	Dependent	G	Dependent	Y	Dependent
3.1.3 Enhanced visual approaches (w/ new procedures - ADS-B & TIS-B)	Y	Dep non-order specific	Y	Dep non-order specific	Y	Dep non-order specific
3.2.1 Approach spacing (for visual approaches)	G	Dep order specific mixed	G	Dep order specific mixed	Y	Dep order specific mixed
3.2.2 Approach spacing (for instrument approaches)	G	Dependent	G	Dependent	Y	Dependent
3.4 Departure spacing/clearance (VMC in radar)		Not Modeled		Not Modeled		Not Modeled
4. Enhanced See and Avoid						
4.1.1 Enhanced visual acquisition of other traffic for see-and-avoid (using ADS-B only)	G	Dependent	G	Dependent	Y	dependent equip
4.1.2 Enhanced visual acquisition of other traffic for see-and-avoid (ADS-B and TIS-B)	Y	Dep non-order specific	Y	Dep non-order specific	Y	Dep non-order specific
4.2.1 Conflict detection	G	Dependent	G	Dependent	Y	dependent equip
4.2.2 Conflict resolution	G	Dependent	G	Dependent	Y	dependent equip
5. Enhanced En Route Air-to-Air Operations						
5.2.1 Pilot situational awareness beyond visual Range		Not Modeled		Not Modeled		Not Modeled
6. Improved Surface Surveillance & Pilot Navigation						
6.1.1 Runway & final approach occupancy awareness (ADS-B only)	Y	Dependent	Y	Dependent	Y	Dependent
6.1.2 Runway & final approach occupancy awareness (ADS-B & TIS-B)	G	Dep mixed non order specific	G	Dep mixed non order specific	G	Dep mixed non order specific
6.2 Airport surface situational awareness	G	Indep	G	Indep	G	Indep
7. Enhanced Surface Surveillance for Controller						
7.1 Enhance existing surface surveillance with ADS-B	G	Not Modeled	G	Not Modeled	G	Not Modeled
7.2 Surveillance coverage at airports w/out existing surface surveillance	G	Dep mixed non order specific	G	Dep mixed non order specific	G	Dep mixed non order specific
8. ADS-B Surveillance in Non-Radar Airspace						
8.2 Radar-like services with ADS-B	G	Indep	G	Indep	G	Indep
8.3 Tower situational awareness beyond visual range	G	Indep	G	Indep	G	Indep
9. Establish ADS-B Separation Standards		Not Modeled		Not Modeled		Not Modeled

Benefit Results – By Benefit Element Constant Year $M

Safe Flight 21 Benefits

Benefit Element	Scenario A	Scenario C	Scenarios B, D & G	Scenario E	Scenario F
Safety Benefits	$5,039	$2,743	$5,556	$5,542	$5,515
Efficiency Benefits	$7,549	$5,369	$7,967	$7,944	$7,668
Total Safe Flight 21 Benefits	**$12,588**	**$8,113**	**$13,522**	**$13,485**	**$13,183**

Safety Benefits

Benefit Element	Scenario A	Scenario C	Scenarios B, D & G	Scenario E	Scenario F
Enh1: Weather Accident Reduction Benefits	$1,020	$758	$1,534	$1,520	$1,494
Enh1: NOTAMs Related Accident Reduction Benefits	$6	$5	$9	$9	$8
Enh2: CFIT Accident Reduction Benefits	$3,188	$1,535	$3,188	$3,188	$3,188
Enh4: Mid-Air Collision Accident Reduction Benefits	$363	$142	$363	$363	$363
Enh8: More Timely Search and Rescue Benefits	$161	$76	$161	$161	$161
Enh6&7: Surface Accident Reduction Benefits	$301	$227	$301	$301	$301
Total Safety Benefits	**$5,039**	**$2,743**	**$5,556**	**$5,542**	**$5,515**

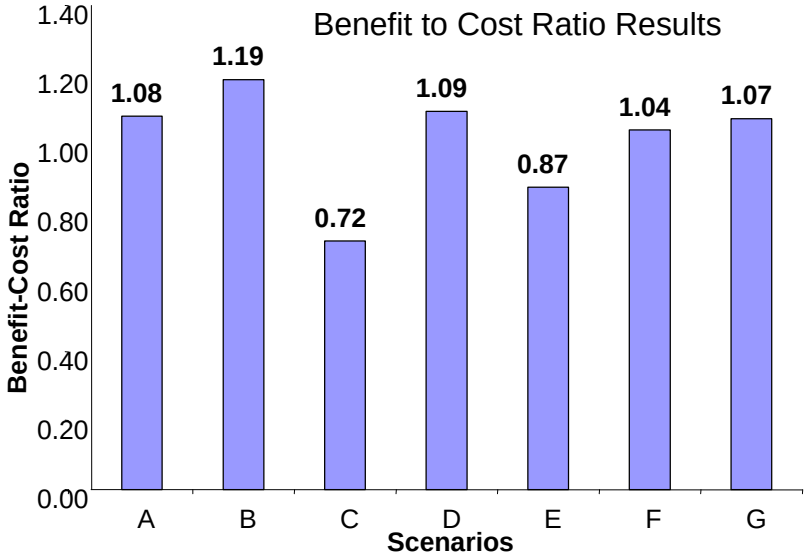
Efficiency Benefits

Benefit Element	Scenario A	Scenario C	Scenarios B, D & G	Scenario E	Scenario F
Enh1: More Efficient Routes in Adverse Weather	$974	$888	$1,391	$1,368	$1,092
Enh3: Reduction in MVMC Arrival Delays	$1,173	$651	$1,173	$1,173	$1,173
Enh6: Reduction in Taxi Times Due to Pilots Enhanced Situational Awareness	$3,030	$1,983	$3,030	$3,030	$3,030
Enh8: Reduction in SVFR Delays	$0	$0	$0	$0	$0
Enh8: More Efficient Search and Rescue Benefits	$1	$1	$1	$1	$1
Enh3&7: Reduction in Arrival and Departure Delays	$2,371	$1,847	$2,371	$2,371	$2,371
Total Efficiency Benefits	**$7,549**	**$5,369**	**$7,967**	**$7,944**	**$7,668**

Benefit Results – By Application Constant Year $M

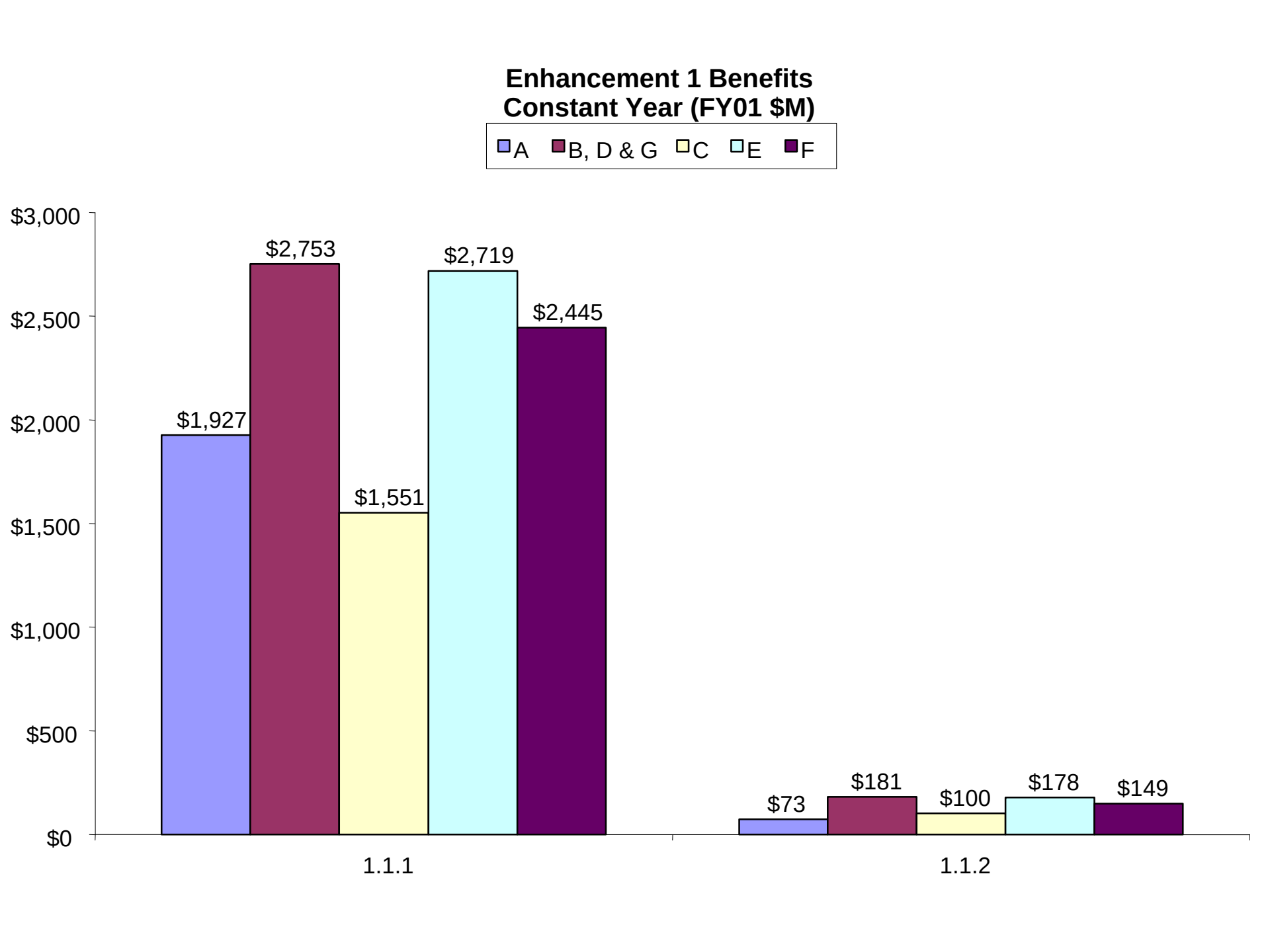
ENHANCEMENT	Scenario A	Scenario C	Scenarios B, D &G	Scenario E	Scenario F
1.1.1 Initial FIS-B based on today's availability	$1,927	$1,551	$2,753	$2,719	$2,445
1.1.2 Add products such as NOTAMs, lightning, icing, turbulence, real time SUA, and Volcanic ash	$73	$100	$181	$178	$149
2.1 Low cost terrain situational awareness	$1,594	$767	$1,594	$1,594	$1,594
2.2 Increased access to terrain constrained low altitude airspace	$1,594	$767	$1,594	$1,594	$1,594
3.1.1 Enhanced visual approaches (Visual acquisition with existing procedures, ADS-B only)	$0	$0	$0	$0	$0
3.1.2 Enhanced visual approaches (w/ new procedures - ADS-B only)	$921	$406	$921	$921	$921
3.1.3 Enhanced visual approaches (w/ new procedures - ADS-B & TIS-B)	$252	$244	$252	$252	$252
3.2.1 Approach spacing (for visual approaches)	$1,664	$1,421	$1,664	$1,664	$1,664
3.2.2 Approach spacing (for instrument approaches)	$702	$422	$702	$702	$702
3.4 Departure spacing/clearance (VMC in radar)	$0	$0	$0	$0	$0
4.1.1 Enhanced visual acquisition of other traffic for see-and-avoid (using ADS-B only)	$62	$18	$62	$62	$62
4.1.2 Enhanced visual acquisition of other traffic for see-and-avoid (ADS-B and TIS-B)	$115	$71	$115	$115	$115
4.2.1 Conflict detection	$124	$35	$124	$124	$124
4.2.2 Conflict resolution	$62	$18	$62	$62	$62
5.2.1 Pilot situational awareness beyond visual range	$0	$0	$0	$0	$0
6.1.1 Runway & final approach occupancy awareness (ADS-B only)	$154	$92	$154	$154	$154
6.1.2 Runway & final approach occupancy awareness (ADS-B & TIS-B)	$85	$91	$85	$85	$85
6.2 Airport surface situational awareness	$3,077	$2,018	$3,077	$3,077	$3,077
7.1 Enhance existing surface surveillance with ADS-B	$0	$0	$0	$0	$0
7.2 Surveillance coverage at airports w/out existing surface surveillance	$20	$14	$20	$20	$20
8.2 Radar-like services with ADS-B	$163	$77	$163	$163	$163
8.3 Tower situational awareness beyond visual range	$0	$0	$0	$0	$0
9.1.1 Radar augmentation with ADS-B to support mixed equipage in terminal airspace	$0	$0	$0	$0	$0
9.2.1 Radar augmentation with ADS-B to support mixed equipage in en route airspace	$0	$0	$0	$0	$0
Total Benefits	**$12,588**	**$8,113**	**$13,522**	**$13,485**	**$13,183**

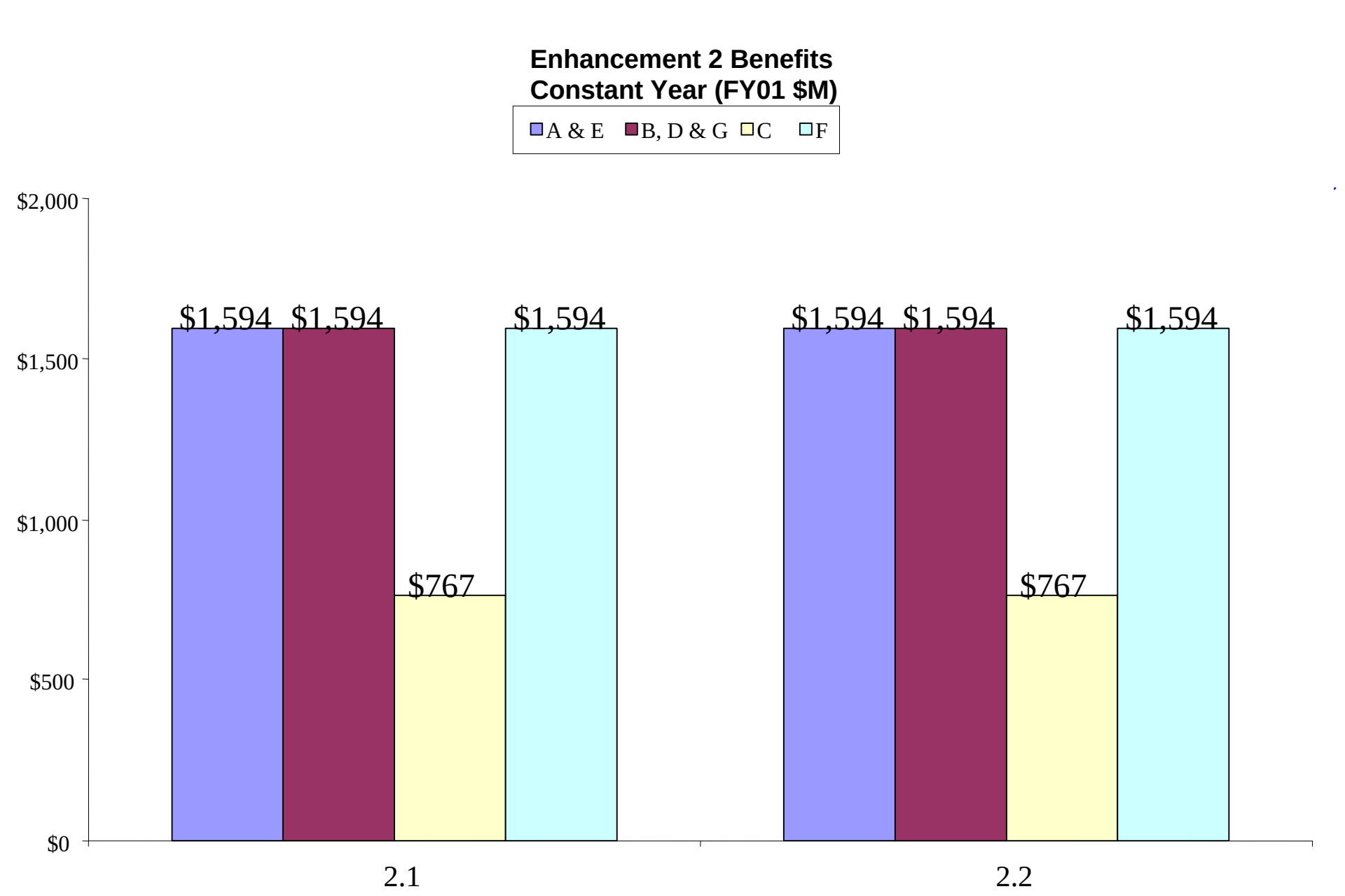
Benefit to Cost Ratio Results

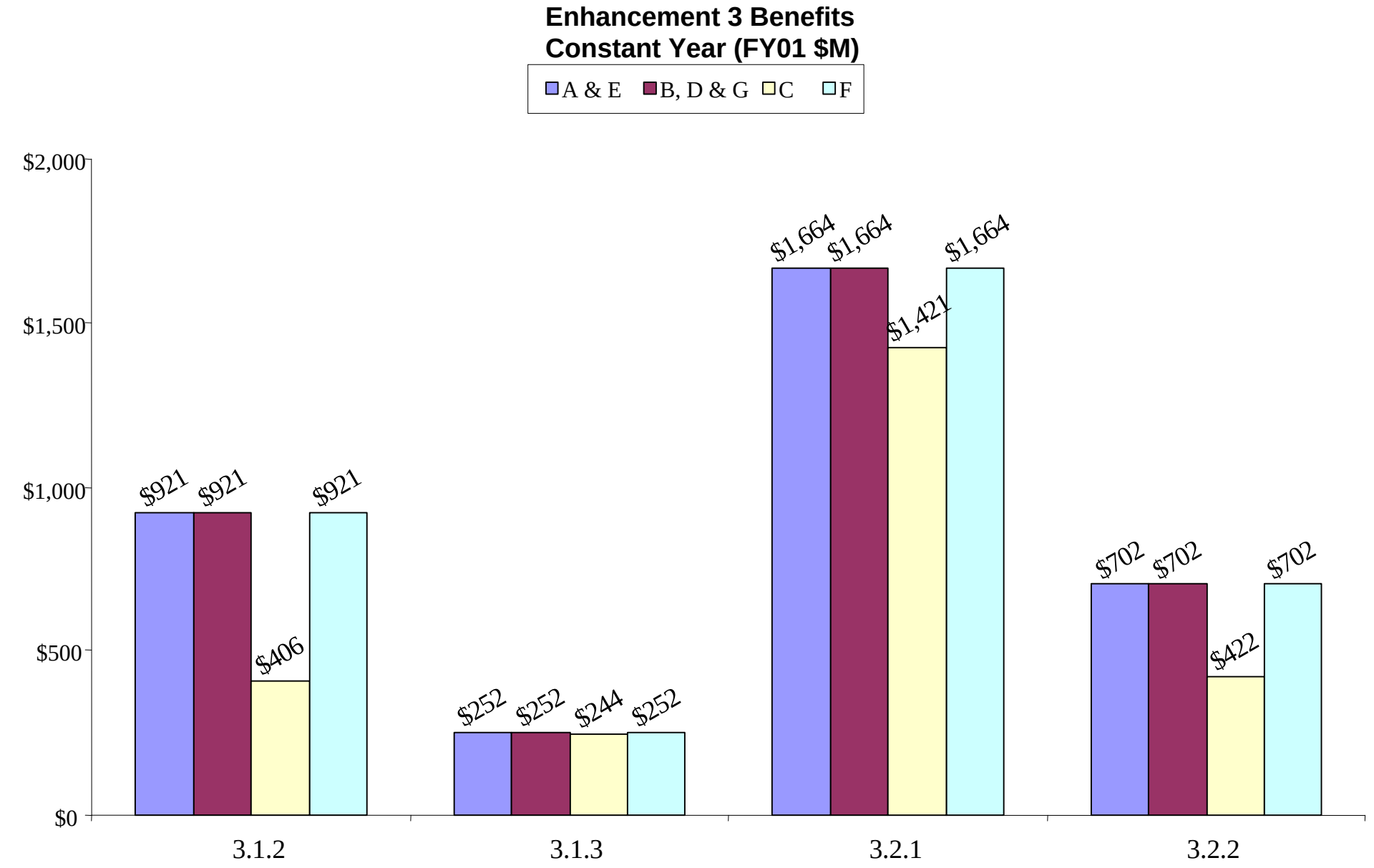


Scenarios	Low/Mid GA Basic	High GA & AT	Air Transport
A	1090 ES		
B	UAT		
C	VDLM4		
D	UAT	1090 ES & UAT	
E	1090 ES	1090 ES & VDLM4	
F	UAT & 1090 ES TX		1090&UAT TX
G	UAT & 1090 RX		1090&UAT RX

Item	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E	Scenario F	Scenario G
FAA Costs	$899	$908	$825	$974	$1,070	$974	$974
Industry Costs	$2,904	$2,814	$2,293	$3,063	$3,958	$3,161	$3,142
Total Present Value Costs ($M)	$3,803	$3,723	$3,118	$4,037	$5,027	$4,135	$4,116
Safety Benefits	$1,636	$1,805	$738	$1,805	$1,796	$1,791	$1,805
Efficiency Benefits	$2,471	$2,612	$1,506	$2,612	$2,598	$2,510	$2,612
Total Present Value Benefits ($M)	$4,107	$4,417	$2,244	$4,417	$4,394	$4,300	$4,417
Net Present Value ($M)	**$304**	**$694**	**($873)**	**$379**	**($634)**	**$166**	**$300**
Benefit-Cost Ratio	**1.08**	**1.19**	**0.72**	**1.09**	**0.87**	**1.04**	**1.07**


Enhancement 1 Benefits
Constant Year (FY01 $M)
A
B, D & G
C
E
F
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
$1,927
$2,753
$1,551
$2,719
$2,445
$73
$181
$100
$178
$149
1.1.1
1.1.2


Enhancement 2 Benefits
Constant Year (FY01 $M)
A & E
B, D & G
C
F
$2,000
$1,500
$1,000
$500
$0
$1,594
$1,594
$767
$1,594
$1,594
$1,594
$767
$1,594
2.1
2.2


Enhancement 3 Benefits
Constant Year (FY01 $M)
A & E
B, D & G
C
F
$2,000
$1,500
$1,000
$500
$0
$921
$921
$406
$921
$252
$252
$244
$252
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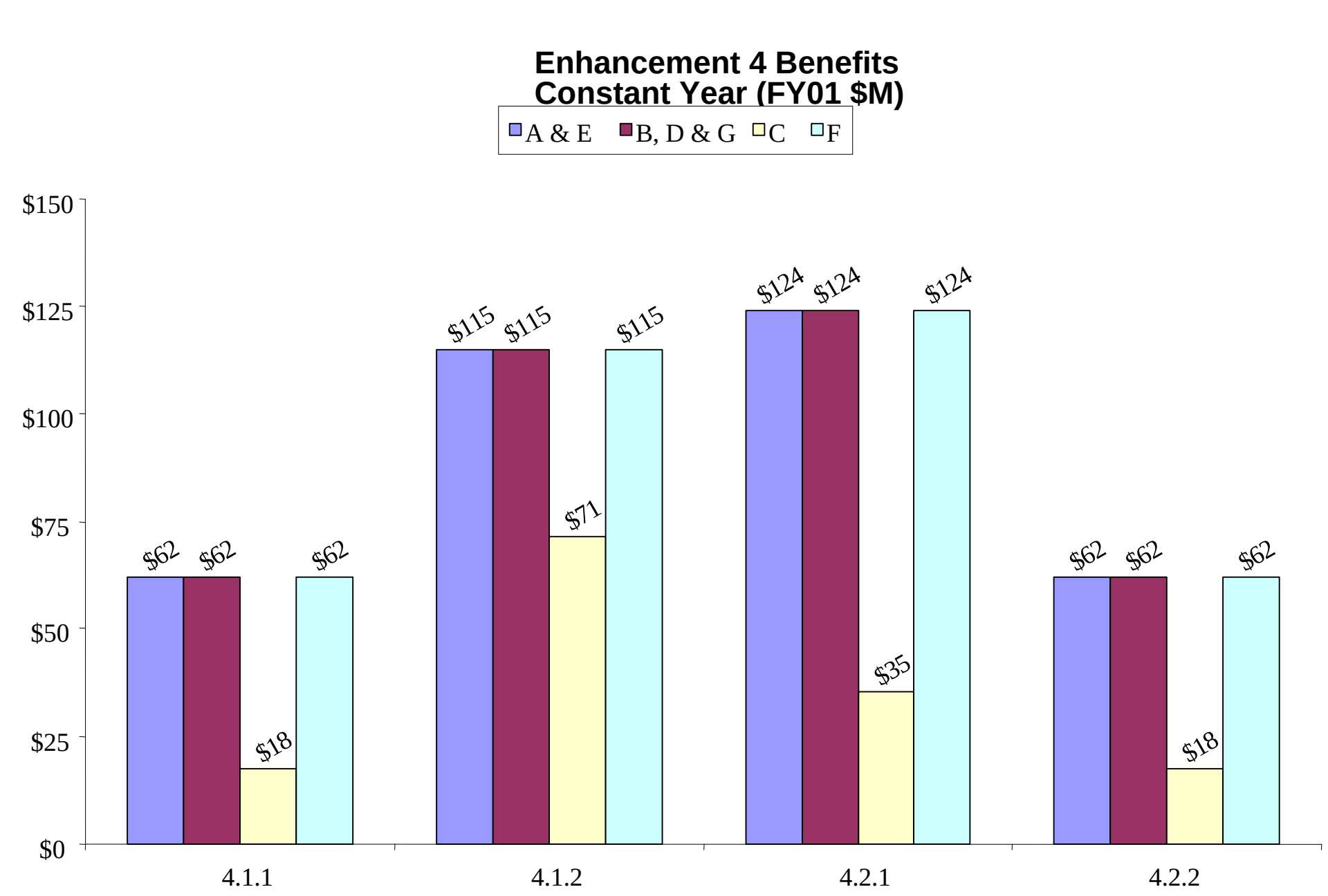
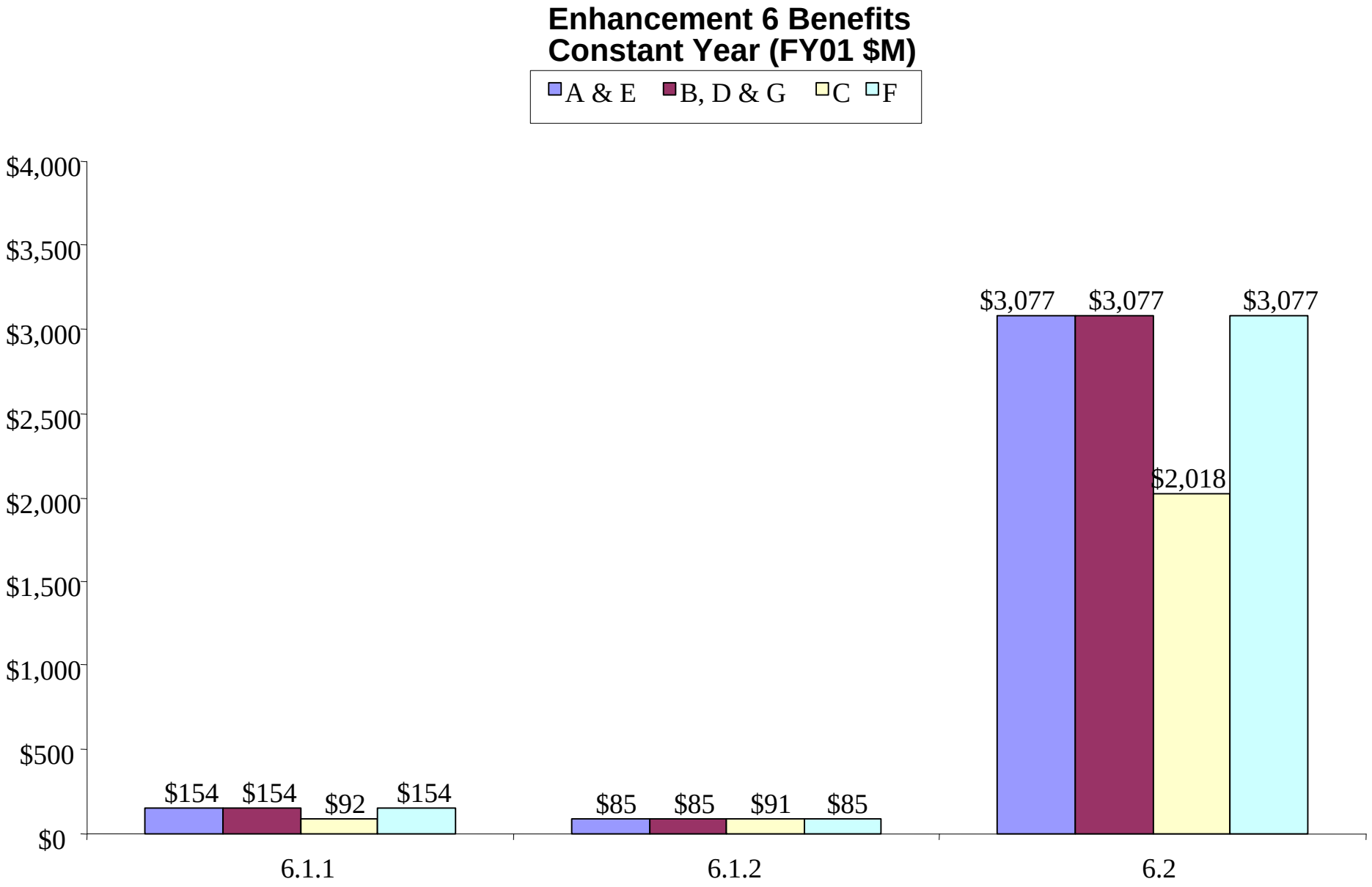
3.2.2


Enhancement 4 Benefits
Constant Year (FY01 $M)
A & E
B, D & G
C
F
$150
$125
$100
$75
$50
$25
$0
$62
$62
$18
$62
$115
$115
$71
$115
$124
$124
$35
$124
$62
$62
$18
$62
4.1.1
4.1.2
4.2.1
4.2.2


Enhancement 6 Benefits
Constant Year (FY01 $M)
A & E
B, D & G
C
F
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$0
$154
$154
$92
$154
$85
$85
$91
$85
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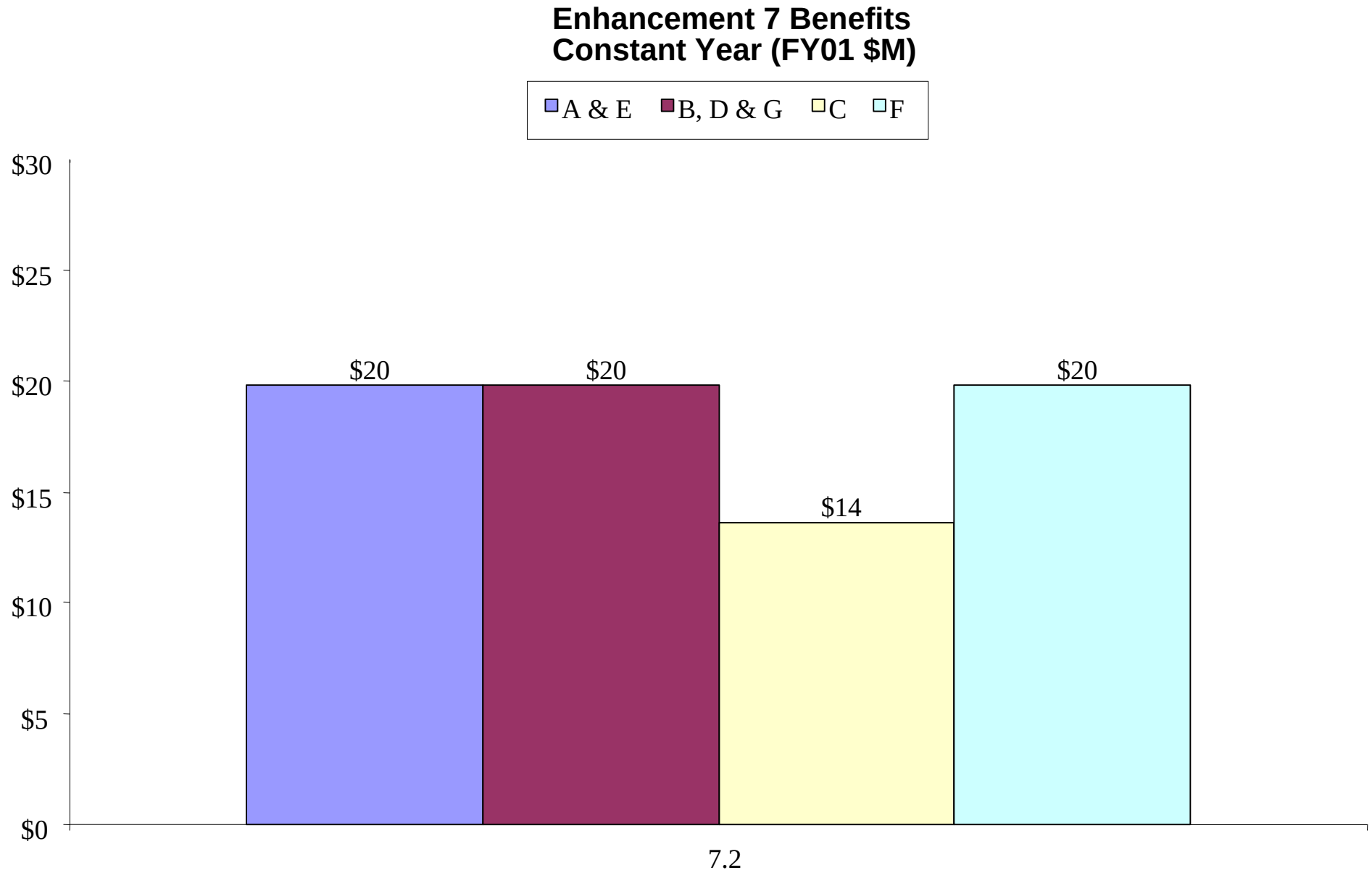
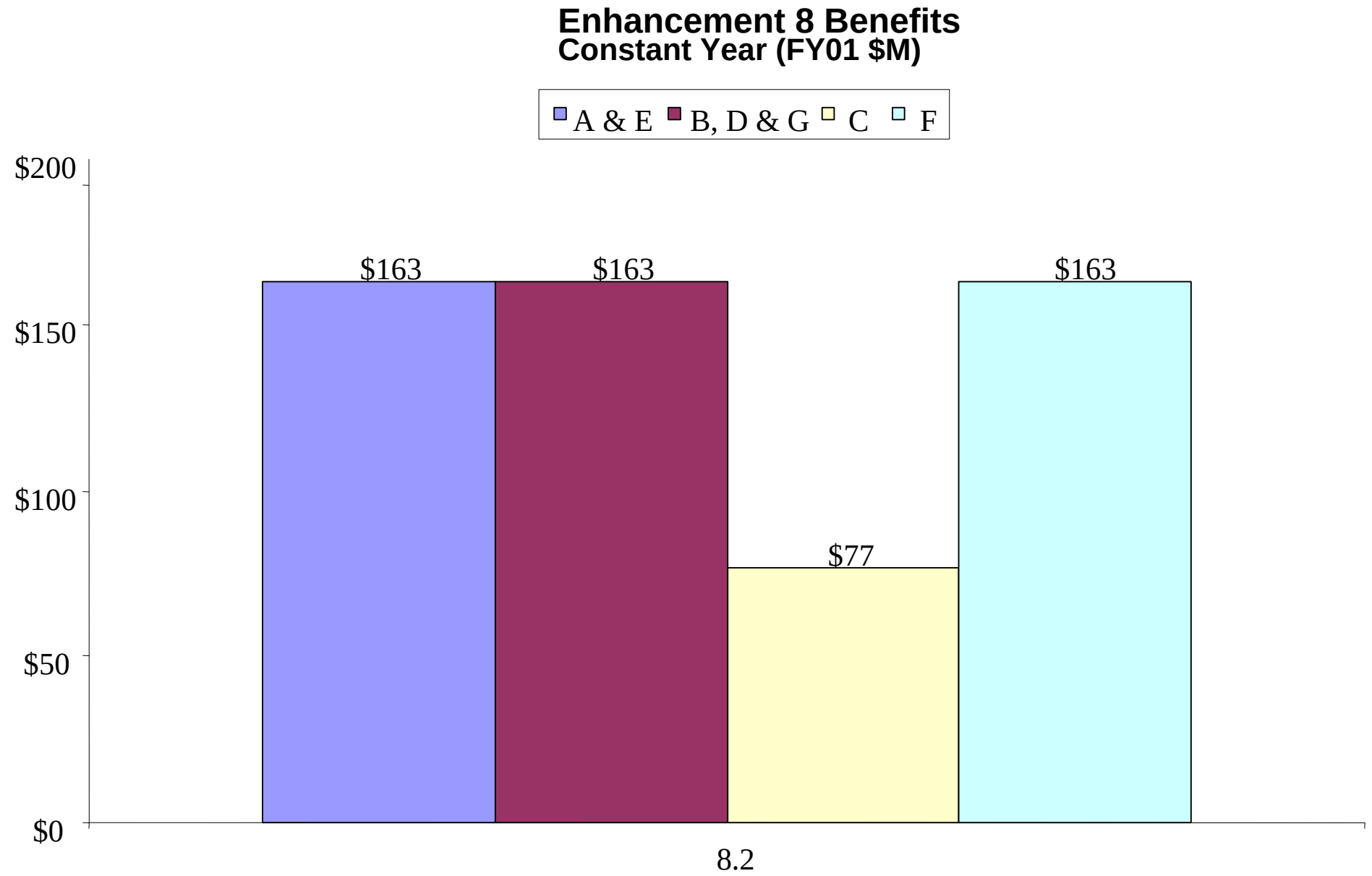
$2,018
$3,077
6.1.1
6.1.2
6.2


Enhancement 7 Benefits
Constant Year (FY01 $M)
A & E
B, D & G
C
F
$30
$25
$20
$15
$10
$5
$0
$20
$20
$14
$20
7.2


Enhancement 8 Benefits
Constant Year (FY01 $M)
A & E
B, D & G
C
F
$200
$150
$100
$50
$0
$163
$163
$77
$163
8.2

Caveats

- FIS-B information assumed to be available only through the ADS-B link
- No interim configurations with partial benefits are considered
- Vendor cost estimates do not reflect the common industry practice of providing discounts to fleet customers
  - For Low/Mid GA, initial costs shown. Modeled a quantity discount as equipage goes up
- Vendor developed cost based on varying configuration and market segment assumptions
- In developing point estimates, no weighting factors were applied
- All costs have been adjusted to understanding of initial costs
  - Followed up to resolve any ambiguity with vendors as to the costs that should be provided
    - End user costs (list price) versus vendor costs
    - Time frame for unit costs to be applied (e.g. now versus in 3 years)
- Due to limited data on how user demand will change as costs change, equipage curves do not vary across non-VDL Mode 4 scenarios