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REGULATORY EVALUATION, REGULATORY FLEXIBILITY DETERMINATION, UNFUNDED MANDATES AND TRADE IMPACT ASSESSMENT

REDUCED VERTICAL SEPARATION MINIMUM OPERATIONS IN THE WEST ATLANTIC ROUTE SYSTEM (NPRM, 14 CFR PART 91)

OFFICE OF AVIATION POLICY, PLANS, AND MANAGEMENT ANALYSIS
OPERATIONS REGULATORY ANALYSIS BRANCH
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Executive Summary

This Notice of Proposed Rulemaking (NPRM) will establish airspace in the New York Oceanic portion of the West Atlantic Route System (WATRS) in which reduced vertical separation minimum (RVSM) may be applied. The existing Federal Aviation Regulations (FAR) section reduces the vertical separation minimum from 2,000 feet to 1,000 feet between FL 290 and FL 410 in certain designated airspace in the North Atlantic(NAT). RVSM in the NAT was implemented on March 27, 1997. RVSM in the Pacific (PAC) was implemented on February 24, 2000. This action is intended to increase the number of available flight levels in WATRS, enhance airspace capacity, permit operators to fly more fuel/time efficient tracks and altitudes, and enhance air traffic controller flexibility by increasing the number of available flight levels, while maintaining an equivalent level of safety.

The FAA estimates that this final rule will cost U.S. operators $26.0 million for the fifteen-year time period 2001-2015 or $23.3 million discounted. The costs can be considered voluntary as they are incurred only by operators participating in WATRS RVSM. However, operators of non-RVSM aircraft will still be able to fly above or beneath the WATRS RVSM airspace. Benefits will begin accruing in 2001. Estimated benefits, based on fuel savings for the commercial aircraft fleet over the years 2001 to 2015, will be $34.7 or discounted at $18.9 million.

I. Introduction

This document contains a regulatory evaluation for an airspace rulemaking to reduce the vertical separation minimum from 2,000 feet to 1,000 feet for aircraft operating between flight levels 29,000 (FL 290) to 41,000 (FL 410) in the WATRS airspace. It also contains an initial regulatory flexibility determination, which is required by law, an international trade impact statement, which is required by the Office of Management and Budget (OMB), and an unfunded mandate assessment, which is required by law.

This NPRM will add WATRS RVSM airspace to FAR section 91.706 and Appendix G. The final rule will impose additional aircraft and operator requirements. These requirements include: meeting the specified altimetry system error, having an automatic altitude keeping capability, and having an altitude alert system. These requirements must also be verified and maintained for RVSM operations in WATRS airspace. RVSM was successfully implemented in the North Atlantic (NAT) on March 27, 1997 and in the Pacific (PAC)on February 24, 2000. RVSM implementation in WATRS is tentatively scheduled for November 2001.

II. History and Discussion of the NPRM

The appropriate amount of vertical separation standard above Flight Level 290 has been a matter of discussion since the mid-1950s. Originally, the vertical separation standard was 1,000 feet at all altitudes, and high altitude flight was possible for only a small number of military aircraft. Advances in technology eventually gave transport and general aviation (GA) aircraft the ability to operate at higher altitudes, resulting in increased traffic along high altitude route structures. In the 1950s, a vertical separation minimum of 2,000 feet was arbitrarily established between aircraft operating above FL 290. This minimum is specified in § 91.179 for continental U.S. airspace.

As the number of aircraft capable of operating at higher altitudes increased, competition for the higher altitudes also increased. This competition for the higher altitudes, together with worldwide fuel shortages and increasing fuel prices, sparked an interest in the early 1970s in implementing a reduced vertical separation minimum above FL 290. In 1973, the Air Transport Association (ATA) petitioned the Federal Aviation Administration (FAA) for a rule change to reduce the vertical separation minimum for aircraft operating above FL 290 to the original separation standard of 1,000 feet. The petition was denied in 1977 in part because (1) aircraft altimeters had not improved sufficiently, (2) improved maintenance and operational standards had not been developed, and (3) altitude correction equipment was not available in all aircraft. In addition, the cost of re-equipping certain aircraft was considerable. On the basis of all available information, the FAA decided that granting the petition at that time will adversely affect safety.

Improvements in altimetry system performance, provided renewed impetus to reduce the vertical separation standard above FL 290. Air data computers (ADCS) provided an automatic means of correcting the known static source error which resulted in improved aircraft altitude-measurement performance. Altimeters were improved with enhanced transducers or double aneroids for computing altitudes. In addition, the advent of transponded Mode C altitude allowed air traffic control (ATC) within secondary surveillance radar (SSR) coverage to monitor flight level.

Thus, in 1982, member States of the International Civil Organization (ICAO) Reduced General Concept of Separation Panel (RGCSP), including the United States, initiated programs to study the feasibility of safely reducing the vertical separation minimum at and above FL 290. These programs included: studies of precision radar data to analyze aircraft vertical performance, analytical development of performance requirements necessary for safe implementation of a 1,000-foot vertical separation minimum above FL 290, and application of collision risk methodology to statistically evaluate the safety of future operations in a reduced separation environment. The results showed that the risk associated with operating in the RVSM environment (2.5 fatal accidents due to midair collisions, per billion flying hours or one midair collision every 100 to 150 years) will be acceptable. A further discussion of this is found Appendix A.

In conclusion, these improvements have provided renewed impetus to investigate reducing the vertical separation standard above FL 290 again.

This final rule will revise FAR section 91.706. The revised section to the FAR will permit the reduction in vertical separation minimum from 2,000 feet to 1,000 feet in the WATRS airspace in addition to the NAT and PAC. The rule will also require the aircraft of operators flying above FL 290 to meet altimetry system error requirements, automatic altitude keeping requirements, and altitude alert system requirements to qualify for RVSM operations.

TCAS II Version 7 is included in this rule as described in the preamble. There is no economic impact to operators upgrading to TCAS II Version 7 due to their upgrading for other international requirements.

III. Costs and Benefits

The analysis described in this regulatory evaluation is based on the following assumptions:

- All costs and benefits are presented in 2000 dollars.
- Projections of the current air carrier and general aviation fleet populations are current as of 2000.
- A discount rate of 7 percent is applied.
- Benefits of RVSM implementation will begin to accrue in 2001.
- Aircraft operator and ATC costs will begin to accrue in 2001; therefore, the 15-year period examined in this regulatory evaluation is 2001 through 2015.
- The implementation may call for phasing in RVSM initially only on a limited number of flight levels. However, this analysis assumes that there will be no phased implementation period.

Based on an analysis by CSSI, Inc, which was updated and adopted by the FAA, this final rule will cost U.S. operators $26.0 million for the fifteen-year time period 2001-2015, or $23.3 million discounted. The costs can be considered voluntary as they are incurred only by operators participating in WATRS RVSM. However, operators of non-RVSM aircraft will still be able to fly above or beneath the WATRS RVSM airspace. The potential quantifiable benefits are based on fuel savings for the commercial aircraft fleet. The benefits will begin accruing in 2001. The fuel savings are estimated at $34.7 million or $18.9

million discounted over the years 2001 to 2015. Safety will not be adversely impacted as a result of this rulemaking.

A. Costs

The cost of the following elements of RVSM implementation will be considered:

- Aircraft Airworthiness Approval
- Monitoring
- ATC
- Operator Training

1. Aircraft Airworthiness Approval Costs

Under the final rule, WATRS operators seeking RVSM approval, will be required to ensure that their aircraft meet various equipment and altimetry system requirements. These requirements are contained in manufacturer's service bulletins have been developed for each specific aircraft type. The estimated costs associated with these requirements are grouped by aircraft type for both commercial and GA aircraft (See Table 1).

Table 1. Manufactures' Service Bulletin Completion Costs				
Type	Series	Estimate	Source	Comments
B747	100/200	$ 58,373.11	FAA Survey 12/97 and OWG Survey 6/97	
B747	400	$ 33,333.33	OWG Survey 6/97	
B757		$ 50,714.29	FAA Survey 12/97 and OWG Survey 6/97	
DC10		$ 2,235.29	OWG Survey 6/97	
MD11		$ 2,235.29	Engineering analysis, same as DC10	
DC8		$285,714.29	FAA Survey 12/97	
L101		$ 20,000.00	OWG Survey 6/97	
B737		$ 50,714.29	Engineering analysis, same as B757	
B727		$ 50,714.29	Engineering analysis, same as B757	
DC9	82,83	$ 2,235.29	Manufacturer	
B767		$ -	Manufacturer	Visual inspection only
B777		$ -	Manufacturer	Visual inspection only
A300		$ -	Manufacturer	Visual inspection only
A320		$ -	Manufacturer	Visual inspection only
A330		$ -	Manufacturer	Visual inspection only
A340		$ -	Manufacturer	Visual inspection only
CL60	1A	$ 62,500.00	Manufacturer	
CL60	3A/3R	$ 17,500.00	Manufacturer	
CL60	604	$ -	Manufacturer	
GULF	G5	$ -	Manufacturer	
GULF	G4	$ 14,000.00	Manufacturer	
GULF	G3	$ 14,000.00	Manufacturer	S/N 427 and higher
GULF	G3	$197,000.00	FAA Survey 12/97	S/N 426 and lower
GULF	G2	$189,500.00	Manufacturer	
F2TH		$ 15,000.00	Manufacturer	
F900		$ 15,000.00	Manufacturer	
FA50		$200,000.00	Manufacturer	
FA20		$ 15,000.00	Manufacturer	
H25B		$ 19,000.00	Manufacturer	
LJ60		$ 13,000.00	Manufacturer	
C750		$ -	Manufacturer	
C650		$ 22,000.00	Manufacturer	
ASTR		$ 40,000.00	Manufacturer	

These estimates represent the cost of the engineering work associated with making an aircraft RVSM compliant or the airworthiness approval cost.

It is necessary to determine the actual operators and aircraft types utilizing the WATRS airspace because RVSM has been successfully implemented in the NAT and PAC and many US operators already have RVSM approval for some of their aircraft. In addition, some commercial operators fly aircraft in the NAT, the Pacific, and WATRS while others have separate fleets of aircraft that operate in one geographic region. GA operators do not fly scheduled routes and many have been approved for RVSM operations on the basis of actual or potential NAT and PAC flights. In order to determine the U.S. operators in WATRS and the type of aircraft they fly, a sample of Enhanced Traffic Management System (ETMS) data from WATRS oceanic airspace was studied. The 44-day data sample of WATRS traffic consisted of 5 days from 9 separate months from 1999. ETMS data is comprised of actual aircraft traffic data that identifies operators, aircraft types, and the frequency of operations. For the US commercial carriers, the WATRS operator and aircraft type information from ETMS data was combined with projected aircraft fleet data from an FAA WATRS RVSM Survey and approved aircraft data from the NAT Central Monitoring Agency (CMA) and the Asia/Pacific Aircraft Registry and Monitoring Organization (APARMO). The results of this analysis provide the number of aircraft that need to be airworthiness approved or upgraded for RVSM, by aircraft type, for each US WATRS operator (See Table 2).

Table 2 Commercial Aircraft Upgrade Costs

Airline/Operator	AC Type	AC Series	Total Fleet Size	Oper in WATRS	Future Oper in WATRS	RVSM Approved	To Upgrade	$ per A/C	Total
American Airlines	B757	200	102	59	59	10	49	$ 50,714.29	$ 2,485,000.21
	A300	600ER	10	10	10	10	0		
	MD11		11	11	11	11	0		
	B767	200/300	79	71	71	71	0		
	A300	600	25	25	25	0	25	$ -	$ -
	B777	200	12	12	31	12	0		
	B727	200	76	76	24	0	0		
American Trans Air	B757	200	11	11	11	11	0		
	L1011	100	14	14	14	14	0		
	L1011	500	5	5	5	5	0		
	B727	200	28	2	2	2	0		
American International	B747	100	2	0	0	2	0		
	B747	200	5	5	5	5	0		
	L1011		6	2	2	5	0		
	DC-8	62	4	1	1	0	0		
	DC-8	63	2	0	0	0	0		
Arrow Airways International	DC-8	62	7	7	7	0	0		
	DC-8	63	3	3	3	0	0		
	L-1011	200	3	3	3	0	3	20,000.00	$60,000.00
Continental Airlines	B737	700	36	36	36	36	0		

Table 2 Commercial Aircraft Upgrade Costs

Airline/Operator	AC Type	AC Series	Total Fleet Size	Oper in WATRS	Future Oper in WATRS	RVSM Approved	To Upgrade	$ per A/C	Total
	DC10	30	31	31	31	31	0		
	B737	800	38	38	38	38	0		
	B757	200	38	38	38	38	0		
Delta Airlines	B757	200	100	1	?	0	25	$ 50,714.29	$ 1,267,857.25
	B767	200/300	100	1	?	0	60	$ -	$ -
DHL Worldwide Express	DC8	73	7	7	7	0	7	$285,714.29	$ 2,000,000.00
	B727	100	11	11	0	0	0		
	B727	200	8	8	8	0	0		
	A300	B4	5	5	5	0	0		
Evergreen International	B747	100	7	7	7	7	0		
	B747	200	4	4	4	4	0		
Miami Air International	B727	200	8	8	8	0	0		
North American Airlines	B757	200ER	2	2	2	2	0		
	B737	800	2	2	2	2	0		
Sun Country Airlines	DC10	15	4	0	0	0	4	$2,235.29	$8941.16
	B727	200RE	5	5	0	0	0		
Tower Air, Inc.	B747	100	5	5	5	5	0		
	B747	200	12	12	12	12	0		
Trans World Airlines	B757	200	27	27	27	27	0		
	B767	200	10	10	10	10	0		
	B767	300	9	9	9	9	0		

Table 2 Commercial Aircraft Upgrade Costs									
Airline/Operator	AC Type	AC Series	Total Fleet Size	Oper in WATRS	Future Oper in WATRS	RVSM Approved	To Upgrade	$ per A/C	Total
	DC9	82	41	12	12	0	12	$ 2,235.29	$ 26,823.48
	DC9	83	62	62	62	0	62	$ 2,235.29	$ 138,587.98
U.S. Airways	B757	200	19	19	19	0	19	$ 50,714.29	$ 963,571.50
	B737	400	13	13	13	0	13	$ 50,714.29	$ 659,285.80
United Airlines	A320	200	59	59	59	13	46	$ -	$ -
	B757	200	98	98	98	29	69	$ 50,714.29	$ 3,499,286.01
	B767	300	34	34	34	34	34	$ -	$ -
	B777	200	29	29	29	29	0	$ -	$ -
United Parcel Service	B727	100	51	0	5	0	5	$ 50,714.29	$253,571.45
	B767	300	30	30	0	30	0		
Total			1302	932	856	514	433		$11,362,924.84

As previously mentioned, many GA operators have been approved for RVSM operations on the basis of actual or potential NAT flights. Of the GA aircraft capable of RVSM operations in WATRS, there were 1,189 airworthiness approved for RVSM as of 22 June 2000. (See Table 3).

Table 3. General Aviation Upgrade Costs

A/C	US Registered	RVSM Approved	Months of SB	% Approved per month	33% of 6/00-/01	Cost per A/C	Total
CL60	352	263	36	2%	31	$62,500	$1,937,500
LJ60	133	37	34	1%	11	$13,000	$143,000
GULF G5	47	19	4	10%	10		$0
GULF G4	284	272	34	3%	6	$14,000	$84,000
GULF G3*	38	35	22	4%	3	$14,000	$42,000
GULF G3**	83	48	22	3%	18	$197,000	$3,546,000
GULF G2	183	4	4	1%	10	$189,500	$1,895,000
F2TH	74	60	36	2%	5	$15,000	$75,000
F900	124	124	36	3%	0	$15,000	$0
FA50	205	136	36	2%	23	$200,000	$4,600,000
FA20	29	18	36	2%	4	$15,000	$60,000
H25B	486	89	28	1%	50	$19,000	$950,000
ASTR	89	15	23	1%	13	$20,000	$260,000
C750	87	53	29	2%	20	$0	$0
C650	263	16	29	0%	7	$22,000	$154,000
TOTAL	2477	1189			211		$13,746,500

* Serial # 427 and higher
** Serial # 426 and lower

It is projected that GA aircraft will start seeking approval for WATRS operations in May 2001. Aircraft approval experience gained during the NAT RVSM implementation has shown that many GA operators will seek RVSM approval after service bulletins are released for their aircraft regardless of what airspace they operate in (GPS-Based Monitoring System Operations Coordinator February 1998). These GA operators will seek approval in order to have the flexibility to operate in any airspace where RVSM has been applied. In other words, many GA operators will seek approval for RVSM operations in order to have the flight planning flexibility that RVSM offers, not specifically because operations are planned in RVSM airspace. In order to account for those aircraft seeking approval for WATRS operations, the current observed NAT/PAC aircraft approval rate for each aircraft type can be applied for the period May 2000 to November 2001 (See Table 3). The number of WATRS approvals will be 33% of the observed aircraft approval rate for each aircraft type or half of the remaining unapproved aircraft population.

Any maintenance associated with maintaining aircraft readiness to operate in the RVSM environment will be part of the currently established maintenance/continuous airworthiness program for an operator as documented in the individual aircraft service bulletin for RVSM.

Operational program requirements include flight crew training to ensure familiarity with RVSM operations. Such training will be conducted through the publication and distribution of an RVSM bulletin. The cost of the bulletin is estimated to be $500 for each operator or $114,000.00 for 17 commercial and 211 GA operators.

2. Monitoring Costs

In 1988, the ICAO Reduced General Concept of Separation Panel (RGCSP) agreed that the target level of safety (TLS) should be 2.5 fatal accidents due to midair collisions in 10^9 flying hours (or approximately one midair collision every 100 to 150 years) for determining equipment requirements.[1] To ensure that the TLS is not exceeded, it is necessary to monitor the occurrence of total vertical error (TVE) and other parameters that are critical to safety assessment (e.g., lateral and longitudinal overlap probability). A monitoring system has been developed to monitor TVE and will be applied to the WATRS population to produce estimates of aircraft and flight level geometric height. The WATRS monitoring program will use the global positioning system (GPS)-based monitoring system (GMS) that was originally developed for NAT RVSM operations by the FAA. A central monitoring agency will also be required to oversee the monitoring system and determine the overall height-keeping performance of aircraft operating in WATRS.

A central monitoring organization will be responsible for coordinating with ICAO member states and tracking the overall performance of the monitoring system. The Central Monitoring Agency, U.K. will fulfill this function.

The GMS consists of a portable measurement device and a data collection and processing system. The portable measurement device or GPS-based Monitoring Unit (GMU) includes a GPS

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[1] ICAO, RGSP. Review of the General Concept of Separation Panel, 6th Meeting. Volume 1, December 1988, ICAO Doc. 9536, RGSCP/6.

receiver, a small computer, and power supply contained in a small case, plus two antenna which are fixed temporarily to the inside of the windows of the aircraft to be measured. The GMU records GPS position data throughout the flight of the aircraft. After the flight, the recorded data is processed and differentially corrected using data recorded at ground reference stations. This information is used to accurately determine the geometric height of the aircraft which is compared to geometric height of the nearest flight level determined from meteorological data. Mode C height for the aircraft is obtained separately from radar recordings. The information is used to determine total vertical error, altimetry system error and assigned altitude deviation.

The capital investment to develop the GMS has been made by the NAT RVSM implementation. To meet the monitoring goals for the North Atlantic RVSM implementation, GMUs were built and the infrastructure necessary to collect the data, process the data and determine height-keeping performance was created. This infrastructure is managed by the FAA William J. Hughes Technical Center and consists of the resources required to operate the GMS. The GMS staff performs the following tasks:

- Schedules GMU usage
- Collects GPS data onboard or trains operator to collect data
- Collects Mode C and meteorological data
- Processes data
- Determines height-keeping error
- Reports results

Since the primary goals of the NAT monitoring program have been met, it is expected that the WATRS monitoring effort will take advantage of available NAT and PAC assets. Sufficient GMUs exist to complete the remaining North Atlantic and Pacific monitoring and meet the reduced monitoring requirements of the WATRS monitoring program. The cost of a GMS staff for WATRS monitoring is expected to be similar to the current cost for the North Atlantic monitoring effort. In the 1st year of implementation, the NAT & PAC GMS staff monitored approximately 40 aircraft per month at a cost of $120,000 per month or $3,000 per aircraft (GMS Technical Manager estimate). The WATRS monitoring goals can be summarized as follows:

- For operators with prior RVSM experience: 2 aircraft of each type are required to be monitored.
- For operators with no prior RVSM experience: 3 aircraft of each type are required to be monitored.

Applying the monitoring goals to the WATRS commercial aircraft fleets determined from traffic analysis yields the estimate contained in Table 4. The general aviation estimate in Table 4 is the number of aircraft estimated to be upgraded for WATRS operations from Table 3.

Table 4. RVSM Monitoring Estimate						
Airline/Operator	AC Type	AC Series	Future Oper in WATRS	Monitored	Monitoring Rqmts	Cost @ $3K ea
American Airlines	B757	200 ER	59	0	2	$6,000
	A300	600 ER	10	10	0	
	B767	200/300	71	71	0	
	A300	600	25	0	2	$6,000
	B777	200	31	8	2	$6,000
	B727	200	76	0	2	$6,000
	MD11		11	11	0	
American Trans Air	B757		6	6	0	
	L1011		3	3	0	
American International	B747	100/200	5	5	0	
	L1011		2	2	0	
	DC-8	62	1	0		
Arrow Airways	DC-8	62	7	0		
	DC-8	63	3	0		
	L-1011	200	3	3	2	$6,000
Continental	B737	700	36	0	2	$6,000
	B737	800	38	2	0	
	B757	200	38	15	0	
	DC10	30	31	31	0	
Delta Airlines	B757	200	25	0	2	$6,000
	B767	200/300	60	0	2	$6,000
DHL Worldwide Express	DC8	73	7	0	3	$9,000
	B727	100	0	0	0	
	B727	200	8	0	3	$9,000
	A300	B4	5	0	0	
Evergreen International	B747	100/200	11	11	0	
Miami Air International						
North American Airlines	B757	200ER	2	2	0	
	B737	800	2	0	2	$6,000
Tower Air, Inc.	B747	100	5	0	0	
	B747	200	12	0	0	
Trans World Airlines	B757	200	27	6	0	
	B767	200	10	10	0	
	B767	300	9	6	0	
	DC9	82	12	0	2	$6,000
	DC9	83	62	0	2	$6,000
United Airlines	A320	200	59	0	2	$6,000
	B757	200	98	0	2	$6,000
	B767	300	34	23	0	
	B777	200	37	37	0	
United Parcel Service	B727	100	5	0	2	$6,000
	B767	300	30	20	0	
	DC8	73	0	0	0	
U.S. Airways	B737	400	13	0	2	$3,000

	B757	200	19	0	2	$3,000
			1008	282	38	$114,000
General Aviation					211	$633,000
Total					249	$747,000

The cost to complete the monitoring of the U.S. WATRS aircraft fleet will be $747,000 in 2000 dollars. The total monitoring cost over 15 years is $861,000.00 or $791,664.00 discounted.

3. Air Traffic Control Costs

RVSM implementation in the NAT has shown that controller workload will decrease and controller training for RVSM can be accomplished during the existing training cycle. No Air traffic control costs (ATC) are expected to occur in order to implement RVSM in the WATRS.

Summary of RVSM Implementation Costs

Based on NAT and PAC experience it is expected that the airworthiness approval implementation costs for the commercial carriers will occur as follows:

- 80% of costs 1 year prior to implementation
- 20% of costs 1 year after implementation

It is also expected that 80% of the monitoring costs associated with implementation will occur in the year prior to implementation and 10% will occur in the next two years after implementation. For GA aircraft, 33% of the costs are expected to occur 1 year prior to implementation, 33% of the costs are expected to occur 1 year after, and 33% of the costs are expected to occur the second year after implementation. Flight crew training costs for both GA and commercial operators are expected to occur the year prior to implementation. The FAA estimates that the total cost is $26.0 million or $23.3 million discounted over 15 years (See Table 5).

Table 5. Implementation Costs							
	Commercial A/C Upgrade	GA A/C Upgrade	Total Upgrade	Training/ Monitoring	Total	Discount Rate Factor	Discounted Total
2001	9,090,340.00	4,582,166.66	13,672,506.66	711,600.00	14,384,106.66	.935	13,449,139.73
2002	2,272,585.00	4,582,166.66	6,854,751.66	74,700.00	6,929,451.66	.874	6,056,340.75
2003		4,582,166.66	4,582,166.66	74,700.00	4,656,866.66	.817	3,804,660.06
2004						.764	
2005						.715	
2006						.668	
2007						.625	
2008						.584	
2009						.546	
2010						.511	
2011						.477	
2012						.446	
2013						.417	
2014						.390	
2015						.365	
Total	11,362,925.00	13,746,500.00	25,109,425.00	861,000.00	25,970,425.00		23,310,140.54

B. Benefits

The FAA concludes that implementing RVSM will offer some operational benefits to operators without any reduction in aviation safety. A detailed discussion of how safety is maintained is shown in Appendix A. Estimated benefits, based on fuel savings for the commercial aircraft fleet over the years 2000 to 2015, will be $34.7 million undiscounted in constant 1999 dollars or discounted at $18.9 million.

Fuel Savings

The greater availability of fuel-efficient altitudes and the utilization of efficient cruise climbs will yield fuel savings for commercial operators. No quantifiable benefits are assumed for GA aircraft operators since they typically get their optimum altitude in the current system. To calculate the quantifiable benefits of improved fuel consumption, The MITRE Corporation completed a study of RVSM benefits that estimated the daily fuel savings for all U.S carriers in the WATRS region to be 1.3 %. The study is documented in Appendix B. Total annual savings presented in Table 6 were determined by multiplying the product of the daily fuel savings, 5,230 gallons, and 365 days, by the international jet fuel price of $0.68 per gallon (U.S. Department of Transportation, Federal Aviation Administration. FAA Aviation Forecasts Fiscal Years 1999-2010). In order to account for the

November 2001 implementation date, 62 days was used to calculate the savings for 2001.

Table 6. Fuel Savings			
	Annual Fuel Savings	Discount Rate Factor	Discounted Total
2001	$237,136.00	.935	221,722.16
2002	$1,522,408.88	.874	1,330,585.36
2003	$1,628,284.48	.817	1,330,308.42
2004	$1,745,727.13	.764	1,333,735.53
2005	$1,868,119.55	.715	1,335,705.48
2006	$2,000,936.16	.668	1,336,625.35
2007	$2,142,199.01	.625	1,338,874.38
2008	$2,292,412.95	.584	1,338,769.16
2009	$2,455,215.73	.546	1,340,547.79
2010	$2,628,365.86	.511	1,343,094.96
2011	$2,812,481.59	.477	1,341,553.72
2012	$3,011,789.38	.446	1,343,258.06
2013	$3,223,750.75	.417	1,344,304.06
2014	$3,449,121.26	.390	1,345,157.29
2015	$3,692,812.07	.365	1,347,876.41
Total	$34,710,760.80		$ 18,972,118.13

Value-Added Benefits

In addition to fuel savings, many non-quantifiable or value-added benefits will result from the implementation of RVSM in WATRS. Input from air traffic managers, controllers, and operators has identified numerous additional benefits.

Through implementation of RVSM in the North Atlantic (NAT) and Pacific (PAC) regions, operators and controllers have realized some additional benefits. The major additional benefits as identified by air traffic managers and controllers are:

- Enhanced capacity
- Reduced airspace complexity
- Decreased operational errors in these regions
- Reduction of user-requested off course climbs for altitude changes
- Improved flexibility for peak traffic demands
- More options in deviating aircraft during periods of adverse weather

The benefits outlined above for RVSM in the NAT and PAC regions are anticipated in WATRS as well. There should be expected efficiencies through reduced airspace complexity, increased flight levels, and fewer altitude changes with crossing traffic.

Operators can expect increased performance due to greater airspace capacity eliminating current restrictions to desired airspace. Operators can also expect increased aircraft performance and decreased delays due to improved airspace efficiency. Specific benefits cited by aircraft operators are:

- Decreased flight delays

- Improved access to desired flight levels
- Reduced average flight times
- Increased availability of step climbs
- Increased likelihood of receiving a clearance for weather deviations
- Seamless, transparent, and harmonious operations between the NAT and WATRS regions
- Consistent procedural environment throughout the entire flight
- Reduced impact of adverse weather by permitting aircraft deviations to other airways without any efficiency loss.

Increased user satisfaction should be obtained with the resultant benefits of implementing RVSM in WATRS.

The benefits described in this section are compelling in number and operational impact. These benefits are also significant in that they are enjoyed both by air traffic service providers and aircraft operators.

IV. Conclusion

The FAA estimates that this final rule will cost U.S. operators $26.0 million for the fifteen-year time period 2001-2015 or $23.3 million, discounted. Estimated benefits, based on fuel savings for the commercial aircraft fleet over the years 2001 to 2015 will be $34.7 million or $18.9 million, discounted. Considering the value-added benefits to air traffic management and operators cited on pages 23-25 and the fuel savings to operators, RVSM should be implemented in WATRS.

V. Initial Regulatory Flexibility Determination

The Regulatory Flexibility Act of 1980 establishes as a principle of regulatory issuance that agencies shall endeavor, consistent with the objective of the rule and applicable statutes, to fit regulatory and informational requirements to the scale of the business, organizations, and governmental jurisdictions subject to regulation. To achieve that principle, the Act requires agencies to solicit and consider flexible regulatory proposals and to explain the rational for their actions. The Act covers a wide-range of small entities, including small businesses, not-for-profit organizations and small governmental jurisdictions.

Agencies must perform a review to determine whether a proposed or final rule will have significant economic impact on a substantial number of small entities. If the determination is that it will, the agency must prepare a regulatory flexibility analysis (RFA) as described in the Act.

However, if an agency determines that a proposed or final rule is not expected to have a significant economic impact on a substantial number of small entities, section 605(b) of the 1980 Act provides that the head of the agency may so certify and an RFA is not required. The certification must include a statement providing the factual basis for this determination, and the reasoning should be clear.

Operators that met the Small Business Administration (SBA) small entity criteria were parsed from the 44-day traffic sample of ETMS data. These operators were cross-referenced with the Central Monitoring Agency (CMA) and the Asia Pacific Approvals and Monitoring Organization (APARMO) databases to determine if they operated any RVSM-approved aircraft. The small entity operators with RVSM-approved aircraft were not considered further in this impact determination.

The list of potential small entity operators, taken from the traffic sample, was used to identify six operators currently reporting financial data to the FAA Bureau of Transportation Statistics. Revenue information for these small entities for year 1999 was obtained from the *Air Carrier Financial Statistics Quarterly*. The operators were then ranked with respect to their total operating revenue. Using this financial data, the impact threshold of $305,540.00 was determined for the six small entity operators. The impact threshold, which is calculated as 1% of the 1999 median impacted small business annual revenues, was compared to the cost of compliance (see table 6).

TABLE 6. SUMMARY OF INITIAL RFA DETERMINATION OF ECNONOMIC IMPACT					
Air Carrier		Number of Employees	1% of 1999 Median Impacted Small Business Annual Revenues	Cost of Compliance	Significant Economic Impact? Y/N
LARGE REGIONALS:					
1	*Champion Air*	200	305,540	283,428.59	N
MEDIUM REGIONALS:					
1	*Capital Cargo International*	205	305,540	308,785.74	Y
2	*Pro Air, Inc.*	275	305,540	131,285.72	N
3	*Reliant Airlines, Inc.*	100	305,540	34,852.93	N
4	*Sunworld International*	65	305,540	53,714.29	N
5	*Tradewinds International*	180	305,540	57,500.00	N

Sources: U.S. DOT, Bureau of Transportation Statistics, Air Carrier Financial Quarterly for 1999 (4th Quarter December 1999/1998); In addition, employment information was obtained from the operators.

As only one small entity operator was found to be impacted by the implementation of RVSM in WATRS. moreover, these costs are not mandated by the FAA. These costs will be voluntarily incurred by those small operators who wish to participate in the RVSM program in WATRS. The FAA, therefore concludes that a substantial number of small entity operators would not be significantly affected by the proposed rule (see Table 6).

VI. International Trade Impact Statement

The Trade Agreement Act of 1979 prohibits Federal agencies from engaging in any standards or related activities that create unnecessary obstacles to the foreign commerce of the United States. Legitimate domestic objectives, such as safety, are not considered unnecessary obstacles. The statute also requires consideration of international standards and where appropriate, that they be the basis for U.S. standards. In addition, consistent with the Administration's belief in the general superiority and desirability of free trade, it is the policy of the Administration to remove or diminish to the extent feasible, barriers to international trade, including both barriers affecting the export of American goods and services to foreign countries and barriers affecting the import of foreign goods and services in the United States.

In accordance with the above statute and policy, the FAA has assessed the potential effect of this proposed rule and has determined that it will impose the same costs on domestic and international entities and thus has a neutral trade impact.

VII. <u>Unfunded Mandates</u>

The Unfunded Mandates Reform Act of 1995 (the Act), enacted as Pub. L. 104-4 on March 22,1995, is intended, among other things, to curb the practice of imposing unfunded Federal mandates on State, local, and tribal governments.

Title II of the ACT requires each Federal agency to prepare a written statement assessing the effects of any Federal mandate in a proposed or final agency rule that may result in a $100 million or more expenditure (adjusted annually for inflation) in any one year by State, local, and tribal governments in the aggregate, or by the private sector; such as a mandate is deemed to be a "significant regulatory action".

This proposed rule does not contain such a mandate. Therefore, the requirements of Title II of the Unfunded Mandates Reform Act of 1995 do not apply.

APPENDIX A

Safety Benefits Analysis

The FAA's William J. Hughes Technical Center measured the change of safety by using work developed by North Atlantic Systems Planning Group (NATSPG) and ICAO's RGCSP.[2] They used the Reich[3] collision risk model, which expresses risk in terms of specific quantifiable parameters. A detailed description of the model is found in the NATS RVSM Guidance Material .

The basic element of the risk evaluation method is the target level of safety (TLS), which expresses the level of risk deemed acceptable. The TLS is an index against which the calculated risk can be compared to help determine if operations in the airway system under consideration are safe. The TLS for this application represents the expected number of fatal accidents per aircraft flight hour in a given airway system due to decreased vertical separation between aircraft at adjacent flight levels. Because separation standards are meant to control fatal accidents, the TLS is expressed in units of fatal accidents rather than the severity of the fatal accident.

The current TLS of 2 fatal accidents per 100 million flight hours has been used in the Minimum Navigation Performance Specifications (MNPS) airspace since the late

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[2] See Review of the General Concept of Separation Panel, 6th Meeting Volume 2, December 1988, ICAO Doc. 9536, RGCSP/6.

[3] See Pacific RVSM Guidance Material, January, 1999

1970s.[4] The NAT Guidance Material states that through examination of U.S. accident data and related information, such as historical data, midair collision data, and near-midair collision data, a regional TLS of 2.5 fatal accidents in 1,000 million flying hours resulting from 1,000-ft vertical separation was established with the required equipment. This TLS is an order of magnitude more stringent than the current level. Therefore, it was determined that the risk associated with operating in the RVSM environment will be acceptable.

The method described for implementing this 1,000 foot vertical separation standard was based on collision risk modeling and an accepted level of safety. A period of 100 to 150 years between midair collisions is considered acceptable in high density traffic areas. If the same separation standard were applied to the North Atlantic airspace, where traffic density is relatively low, the standard theoretically could result in a period of approximately 700 years between midair collisions.

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[4] Brooker, P., and Ingham, T., Target Levels of Safety for Controlled Airspace, CAA Paper 77002, February 1977.

APPENDIX B

Assessing User Benefits for WATRS RVSM

MP 00W0000158

MITRE PRODUCT

Potential User Benefits for WATRS RVSM Phase II Implementation

July 2000

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Sponsor: Federal Aviation Administration
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Abstract

Reduced Vertical Separation Minima (RVSM) have been proposed for implementation in the Western Atlantic Track System (WATRS) region of the New York Flight Information Region (FIR). The Phase II implementation would create an exclusive equipage environment in the New York FIR portion of WATRS. Although the actual flight levels have not been firmly agreed upon, the International Civil Aviation Organization (ICAO) rule allows the implementation from FL290 through FL410, inclusive. This report presents the analysis of the potential fuel savings/penalties of implementing WATRS RVSM Phase II. The potential fuel impact of WATRS RVSM Phase II was analyzed by estimating the fuel burn savings and penalties of all RVSM and non-RVSM eligible aircraft. This was determined by examining 15 sample days across all seasons from October 1998 through December 1999. The optimal fuel savings were calculated for all RVSM capable aircraft flying at their optimum altitudes, and a fuel burn penalties were calculated for all non-RVSM capable aircraft to fly outside FL290-410. Developed with the Air Traffic Rules and Procedures Service (ATP) and the Flight Standards Service (AFS), "Altitude for Direction" and "Operational Feasibility" checks were made to impose realism, resulting in an overall net fuel burn savings of approximately 1.2% - 1.3% for all flights in WATRS, with an average savings of 188 pounds of fuel on a per flight basis.

KEYWORDS: WATRS, RVSM, Fuel Burn Modeling, User Benefits Analysis

Acknowledgments

The authors would like to thank a number of contributors to this analysis. We thank Bobby Hamilton for his work in reducing the data from the sample days to those flights that pass through Western Atlantic Track System (WATRS). We are very grateful for the efforts of Mark Huberdeau and Amy Darrow, for thousands of runs of Jeppesen JetPlan4 to populate the Fuel Burn table for the Top 12 aircraft on the generic routes at all altitudes. In support of that effort, we thank Glenn Foster for his part in developing tools to simplify the fuel burn runs. We would like to thank Andy Anderegg for his overall guidance on this task, and Steve Sanders for his technical assistance. We gratefully acknowledge the assistance of our sponsors, Dave Maloy (AFS-410) and Roger Kiely (ATP-130), and thank them for working with us. We appreciate the technical assistance of Dale Livingston (ACT-520) for providing airframe Reduced Vertical Separation Minima (RVSM) certification data and Bob Miller (CSSI) for providing Enhanced Traffic Management System (ETMS) data as a basis for comparison for several sample days. Finally, many thanks to Angela Signore for her efforts in the publication of this report.

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Executive Summary

The Western Atlantic Track System (WATRS) Reduced Vertical Separation Minima (RVSM) Program Phase II will involve the implementation of RVSM for all approved aircraft in the New York Flight Information Region (FIR) portion of WATRS airspace, and the expansion of RVSM transition airspace to include the San Juan Combined Center Radar Approach Control (CERAP) and any remaining portion of Miami Oceanic airspace. Phase II will build upon Phase I, which is planned to expand the RVSM transition areas outside of the New York FIR portion of WATRS airspace into adjacent radar-controller U.S. controlled facilities including Miami, Jacksonville and Washington Air Route Traffic Control Centers (ARTCCs), and perhaps the Fleet Area Control and Surveillance Facility (FACSFAC) for VACAPES (the northern coastal Warning Areas).

The primary difference between the two phases, as it pertains to the WATRS region, is that Phase I expands the geographic region for which the current North Atlantic RVSM rule applies (i.e., approved aircraft that are transitioning to or from the Minimum Navigation Performance Specification, or MNPS, airspace), while Phase II redefines the rule to include approved aircraft that are transitioning to/from the New York FIR within selected flight levels. Similar to Phase I, the primary driver for Phase II is to provide greater access to user preferred altitudes and routes for as many eligible aircraft operating through WATRS that are transitioning to/from the New York Oceanic FIR.

The Phase II implementation will create an exclusive equipage environment in the New York FIR portion of WATRS. Although the actual flight levels have not been firmly agreed upon, the International Civil Aviation Organization (ICAO) rule allows the implementation from FL290 through FL410, inclusive. In this context, exclusive means that only RVSM approved aircraft will be allowed to operate within the RVSM altitude stratum and that non-RVSM approved aircraft (with certain exceptions) may not flight plan into RVSM airspace. In order to provide justification and obtain approval for exclusivity, rulemaking must be conducted to identify the potential benefits to U.S. approved users and the impact to the non-approved users. In support of this effort, The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) was tasked to analyze the potential benefits and penalties by applying the ICAO approved RVSM flight levels.

The potential fuel impact of WATRS RVSM Phase II was analyzed by estimating the fuel burn savings and penalties of all RVSM and non-RVSM eligible aircraft. This was determined by examining 15 sample days across all seasons from October 1998 through December 1999. A breakdown by flight type (U.S., Foreign, Military, General Aviation [GA]) is shown in Figure ES-1. The data indicated that 91 percent of all the flights are potentially eligible for RVSM (see Figure ES-1), based strictly on the ability of an airframe to obtain RVSM approval (i.e., existence of an approved RVSM service bulletin).

The fuel savings estimates for RVSM eligible aircraft were made by first determining the optimum altitude and calculating the associated fuel burn. This was then compared to the calculation of fuel burn for actual altitudes flown, and a determination was made of the delta savings or penalty. The estimates for non-RVSM aircraft were made by determining the fuel savings or penalties associated with these aircraft flying outside the RVSM designated stratum (i.e., at or below FL280, or at or above FL430).

For analysis purposes, fuel burn tables were developed for the "Top 12" airframes flown in the WATRS region (88 percent of all flights – see Figure ES-1). The sample data indicated that 96 percent of the Top 12 aircraft type flights were RVSM eligible. A fuel burn "Rule of Thumb" (3.2 pounds/minute/1000 feet from optimum altitude, based on North Atlantic (NAT) Implementation Management Group (IMG) Cost/Effectiveness (NICE) Programme study historical data was used for all other airframes, of which 52 percent were RVSM eligible.

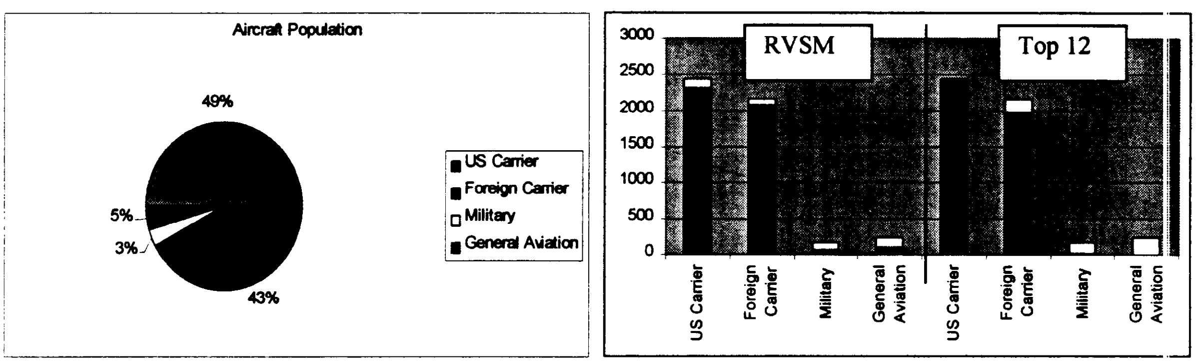


Figure ES-1. Population, RVSM Capability and Top 12 Aircraft Types

The optimal fuel savings were calculated for all potentially RVSM eligible aircraft, which were then adjusted to account for "Altitude for Direction" rules and "Operational Feasibility" checks (i.e., identification and resolution of aircraft pairs over key fixes with less than minimum longitudinal or crossing separation between aircraft), as a means to impose realism on the final results. The cumulative results, broken out by flight types, follow.

U.S. Air Carriers

1) Forty nine percent of the flights through the WATRS region were flown by U.S air carriers.

– Ninety five percent were RVSM eligible.

- Five percent were non-RVSM eligible.

2) Ninety nine percent of U.S. air carriers were categorized in the Top 12 aircraft types, which means that the fuel burn tables were used for estimating the potential impact.

3) A net fuel burn savings of approximately 1.3 - 1.4 percent was estimated for U.S. air carriers within the Top 12 aircraft types. This was consistent across all the sample days.

Foreign Carriers

4) Forty three percent of the flights through the WATRS region were flown by foreign air carriers.

- Ninety six percent were RVSM eligible.

- Four percent were non-RVSM eligible.

5) Ninety one percent of the foreign carriers were categorized in the Top 12 aircraft types, which means that the fuel burn tables were used for estimating the potential impact.

6) A net fuel burn savings of approximately 1.1 percent was estimated for foreign carriers, which was consistent across all the sample days.

Military

7) Three percent of the flights through the WATRS region were flown by military flights.

- Forty percent were RVSM eligible.

- Sixty percent were non-RVSM eligible.

8) Eighty seven percent of the military flights were categorized in Other (not Top 12) aircraft types, which means that the "Rule of Thumb" was used for estimating the potential impact.

9) A net fuel burn savings of approximately 1.0 percent was estimated for military flights within the Top 12 aircraft types. This varied across all the sample days, due largely to the significant variations in flight schedules.

General Aviation

10) Five percent of the flights through the WATRS region were flown by general aviation.

- Forty one percent were RVSM eligible.
- Fifty nine percent were non-RVSM eligible.

11) Ninety seven percent of the GA flights were categorized in Other (not Top 12) aircraft types, which means that the "Rule of Thumb" was used for estimating the potential impact.

12) A net fuel burn savings of approximately 0.3 percent, was estimated for GA flights within the Top 12 aircraft types. This varied across all the sample days, due largely to the significant variations in flight schedules.

Overall Results

13) Ninety one percent of the flights through WATRS are eligible for RVSM approval.

14) Eighty eight percent of all the flights were accounted for in the Top 12 aircraft types.

15) A net 1.3 percent fuel savings was estimated for the Top 12 aircraft types, assuming that they are permitted to fly at their optimum altitudes.

- The savings was reduced slightly (to 1.2 percent) by the imposition of "Altitude for Direction" and "Operational Feasibility" rules.

16) An overall fuel penalty of 5500 - 6500 pounds was estimated for all of the Other (not Top 12) aircraft types (12 percent of all flights), for which the "Rule of Thumb" rule was applied. It should be noted that this penalty is less than 0.5 percent of the fuel savings attributed to the aircraft within the Top 12 aircraft types.

17) A net fuel burn savings of approximately 1.2 - 1.3 percent was estimated for all flights (i.e., U.S., Foreign, Military, GA) in the WATRS area.

18) An average savings of 188 pounds of fuel was estimated on a per flight basis. It should be noted that this can vary greatly by airframe. The average savings is based on the following:

- RVSM flights would save an average of 262 pounds of fuel, and
- Non-RVSM flights would expend an additional average of 570 pounds of fuel.

Section 1

User Benefits for WATRS RVSM Phase II

1.1 Introduction

The primary objective of this analysis was to support of the Notice for Proposed Rulemaking (NPR) process for Western Atlantic Route System (WATRS) Reduced Vertical Separation Minima (RVSM) Phase II, by assessing the expected user benefits for RVSM approved U.S. air carriers through the New York portion of WATRS airspace from the reduction of vertical separation between FL290 through FL410. The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) was directed in this study by Flight Standards Service (AFS) and Air Traffic Rules and Procedures Service (ATP). In the process of conducting this assessment, a flexible methodology was developed that permits additional analyses to be run. In the event that the benefits assessment needs to be reexamined due to some change in the baseline assumptions (e.g., changes in the "direction for altitude" rules) or questions raised by the New York Oceanic Capacity Enhancement Task Force (CETF), the methodology was designed for rapid follow-on analyses.

Additionally, this analysis can be extended to support the CETF in determining the flight levels, by analyzing the effect of a variety of flight level schemes and the corresponding impact to the users (e.g., U.S. air carriers, non U.S. air carriers, general aviation). These analyses have not been scheduled at the time of the publication of this report, but are listed in the possible additional analyses, suggested at the end of this report.

1.2 Measurable Benefits

Assessment of user benefits and penalties was quantified exclusively in terms of fuel burn for the portion of flight that falls within the New York portion of the WATRS region. The goal of this benefits analysis was to demonstrate the amount of fuel that might be saved by 1) permitting RVSM capable aircraft to fly at their optimal altitudes while in WATRS, and 2) requiring non-RVSM equipped aircraft to fly outside the RVSM exclusive altitudes of FL290-410. Fuel burn was assessed for both RVSM approved and non-RVSM approved aircraft and was calculated to account for the following:

19) Preferred RVSM entry altitude into WATRS

20) Step climbs along the actual route of flight through WATRS

21) Revised "altitude for direction" rules (or Rules of the Road) for RVSM in WATRS

22) Operational feasibility (conflicts at key crossings) of flying at optimum altitudes

Each of the conditions above was analyzed in turn, and the reductions in fuel burn benefits from permitting all flights to fly at optimum altitudes was calculated. It was expected that these realism-imposing conditions would reduce the benefits, though the actual results indicated that the impact was not large.

1.3 Assumptions

WATRS RVSM Phase II. The Phase II implementation will create an exclusive equipage environment in the New York Flight Information Region (FIR) portion of WATRS. Although the actual flight levels have not been firmly agreed upon, the International Civil Aviation Organization (ICAO) rule allows the implementation from FL290 through FL410, inclusive. In this context, exclusive means that only RVSM approved aircraft will be allowed to operate within the RVSM altitude stratum and that non-RVSM approved aircraft (with certain exceptions) may not flight plan into RVSM airspace.

Transition airspace. It is recognized that there will probably be user benefits for the portion of flight in the expanded RVSM transition airspace. Since the exact transition areas have not been designated and the point at which the controller would assign the RVSM flight level is unknown, the fuel burn analysis does not attempt to estimate the effects for this portion of the route.

Phase I Benefits. It is recognized that there may be benefits realized through the implementation of RVSM Phase I. Since it is uncertain what benefits will be realized in Phase I (due to the mixed equipage environment), there has been no attempt to adjust the Phase II benefits for potential Phase I benefits. Consequently, the benefits for Phase II calculated in this analysis may be on the higher end if Phase I is successful in applying RVSM to a majority of RVSM eligible aircraft. It should also be noted that since Phase II removes the restriction of having the RVSM transition to/from Minimum Navigation Performance Specification (MNPS) airspace, it is possible that the benefits realized in Phase I may be less in Phase II, since more users would be contending for the same flight levels.

Aircraft Types. For this analysis, aircraft types that have an RVSM service bulletin were considered as RVSM approved. It is recognized that there are alternative plans to get approval for aircraft types that do not have a service bulletin. For the purposes of this analysis, only those aircraft types that currently have an approved RVSM service bulletin were considered for the various assessments. The only exceptions to this were consideration of the L1011 as 100 percent RVSM approved and the B727 as 50 percent approved, as discussed with and approved by the sponsoring agencies, AFS and ATP. Note that service bulletins for these aircraft types have since been issued.

Impact of Winds. Wind data (difference in wind at altitudes) was considered only as the historical monthly averages, for constructing the fuel burn tables using the Jeppesen Flight Planning System (JetPlan4). Thus, wind was only factored in for those aircraft types for which fuel burn tables were built (the Top 12 aircraft types); wind was not considered as a factor for the rest of the aircraft types. The actual wind conditions on the sample data days were not considered, but the days were selected as being weather-benign days, so no unusual weather or winds influenced the data.

Section 2

Analysis Preparation and Source Data

2.1 Flight Data Selection

Upon review of several data sources including Enhanced Traffic Management System (ETMS) and Oceanic Display and Planning System (ODAPS), ODAPS data from the CAASD Oceanic Data Repository (ODR) was chosen for convenience, since the source was available in-house. Examination of sample days showed a high correlation between the ODAPS and the ETMS data sets.

Fifteen data sample days (at least 3 per season) were selected; additional days may be analyzed, as time permits. The strategy for 3-day selection was to get a Thursday, Friday, Saturday sequence to permit analysis of busy times across day borders. The rationale for each day, based on discussions with CAASD ex-dispatchers, was that Thursday is the typical (quieter) weekday, Friday is the transition day to the weekend, and Saturday is a typical (busier) weekend day.

The 15 days selected for analysis were:

October 8, 9, 10, 1998

March 11, 12, 13, 1999

July 15, 16, 17, 1999

October 28, 29, 30, 1999

December 9, 10, 11, 1999

By selecting several sequential days, pushes and lulls across those days would be accommodated. In fact, the data collection was performed for flights from 0800Z Thursday to 0800Z Sunday as the three days, rather than the typical 0000Z, since 0800Z represents a middle-of-night lull.

The weather for those days was assessed to assure that no exceptional weather days were used in the analysis. There was no hurricane activity in WATRS on these dates. Satellite archives were reviewed; there were no severe weather patterns in WATRS. To double check for severe weather, major routes loads were checked for selected days; no use imbalance was seen for the March 1999 and July 1999 samples. Exceptional weather would drastically impact the representative-ness of the data for the day.

Certain data elements were needed from the data set to support this analysis. For each applicable flight in each analysis day, the data needed were:

23) Aircraft type

24) Origin/destination

25) WATRS entry point (waypoint or lat/long) and altitude/time

26) Waypoints in WATRS, with altitude /time

27) WATRS exit point (waypoint or lat/long) and altitude/time

2.2 Fuel Burn Data

In order to assess the fuel burn savings associated with flying at optimum altitudes, several fuel burn modeling methods were considered. The most accurate of the methods available was to use the Jeppesen Flight Planning system (JetPlan4) to develop tables of fuel burn (at optimal altitude and at fixed 1000 foot increments of altitude) for airframes flown in WATRS for sample weights/payloads and sample routes/distances through WATRS. This table would then be used as a reference to conduct the analysis of the flights on each analysis days, by comparing the difference between the actual altitude profile and the associated fuel burn with the determined optimum altitude profile and the associated fuel burn.

Although it proved to be impractical to prepare these tables for all aircraft types flown through WATRS, examination of the sample analysis days showed that the "Top 12" most used aircraft types accounted for 88 percent of the flights through WATRS. Fuel burn tables were prepared (using JetPlan4), considering the following data elements:

28) Aircraft types (12 major types selected from sample of Flight Data)

29) Routes or flight distances (five representative routes selected from sample of Flight Data)

30) Payload weight (fixed at 80 percent of maximum)

31) Altitude (FL250 to FL430)

The result was a fuel burn table for each of the Top 12 aircraft types, that consists of fuel burn data (fuel burn and time in WATRS) for routes vs. altitudes.

For those aircraft types that were not in the Top 12, a single standard fuel burn rate ("Rule of Thumb") was used to estimate fuel burn rates. Previous studies by the North Atlantic (NAT) Implementation Management Group (IMG) Cost/Effectiveness (NICE) Programme outlined a general fuel burn difference of .5 gallon/minute/1000 feet from optimum. Based on this standard, the analysis used the optimum altitudes estimated from the sample analysis days (preferred altitude flown for each aircraft type), and the fuel burn savings estimated at an additional 3.2 pounds of fuel spent, per 1000 feet from optimum altitude, per minute of time in WATRS. A quick validation of the Rule of Thumb, using the Top 12 aircraft types, showed that 3.2 pounds is a high estimate; 1-2 pounds was more accurate for the Top 12 aircraft types. However, 3.2 pounds was still used for the aircraft types that were not in the Top 12, because of the wide variation in the aircraft types.

Table 2-1. RVSM Capability of Selected Airframes (Top 12 in Bold)

Top 12	**RVSM Capable**	**Others**	**RVSM Capable**	**Others**	**RVSM Capable**
A300	**y**	A124	n	FA20	y
A320	**y**	A310	y	FA50	y
B727	**50%**	ASTR	y	G159	n
B737	**y**	B777	y	G4	y
B747	**y**	C130	n	G5	y
B757	**y**	C135	n	GULF	y
B767	**y**	C141	y	H25B/C	n
DC8	**n**	C560	n	IL62	n
DC10	**y**	C650	y	IL96	n
L1011	**(y)**	C750	y	LJ35	n
MD11	**y**	CL60	y	LJ55	n
MD80	**y**	DC9	n	WW24	n

2.3 Direction for Altitude (for Rules or the Road)

Based on discussions with AFS and ATP, the following initial altitude for direction scheme was devised for WATRS with RVSM.

Northbound: FL280, 300-310, 340-350, 380-390, 410
Southbound: FL270, 290, 320-330, 360-370, 400, 430

Westbound (11am-3pm): FL370-380
Eastbound (6pm-12am): FL300, 320, 340

Section 3

Methodology for Analysis Conduct

The WATRS RVSM Phase II fuel burn analysis was conducted according to the following outline, given the sample flight data from ODAPS and the fuel burn data for the Top 12 airframes, plus the Rule of Thumb to calculate fuel burn for those airframes that were not of the Top 12.

32) Determine all **Flights in WATRS**. For each of the 15 sample days in the selected data set, the flight history was examined for all flights that entered/exited WATRS.

33) Determine **Maximum Fuel Savings**. For all flights in each analysis day, a "Best Case" analysis was performed to find out the most fuel savings possible. Every RVSM capable flight entered WATRS at its optimal altitude and remained at this altitude for its entire flight through WATRS. Comparing this RVSM altitude to the current (baseline) altitude flown permitted calculation of the maximum fuel saving possible for each RVSM flight. Every non-RVSM flight that entered WATRS was assigned a flight level above FL410 or below FL290, and remained at this altitude for its entire flight through WATRS. Comparing this altitude to the current altitude flown permitted calculation of the additional fuel spent for each non-RVSM flight. So, for every flight in WATRS on each analysis day:

- from flight origin and destination and the WATRS entry and exit points, determine the entry and exit regions, and the time that the flight is in WATRS.
- categorize the flight on a generic route.
- for the airframe type (Top 12) and the generic route, look up fuel burn for the actual flown (baseline) altitude from the Fuel Burn table; then
  - for an RVSM flight, look up the optimal altitude and fuel burn from the Fuel Burn table; or
  - for a non-RVSM flight, look up the assigned altitude and fuel burn from the Fuel Burn table; and
  - calculate the delta between actual and optimal (RVSM) or assigned (non-RVSM) fuel burn, to get difference in fuel burn for each flight.

- for the airframe type (not Top 12) and the generic route and generic optimal (or assigned for non-RVSM) altitude, calculate the fuel burn difference from the "Rule of Thumb". -
- if the flight performed a step-climb in its actual (baseline) flight, decide if step-climb would add benefit; if so, calculate separate fuel difference and time for the affected portion of the flight.

34) Accumulate the total Optimum fuel burn difference for all aircraft in WATRS for a day.

35) Apply **Altitude for Direction Scheme**. Adjust altitudes of all flights in a day for the "Altitude for Direction" rules and recalculate fuel difference for affected flights.

36) Determine **Operational Feasibility**. For all flights in a day, check traffic densities at altitudes at waypoints or along selected routes; if too dense, adjust selected flights up or down 1000 feet from optimum and recalculate fuel difference for affected flights. Recheck densities with flights at the new altitudes and adjust further if necessary. Go/no-go density levels were determined by ATP and the New York Center (ZNY) for operational feasibility.

37) Aggregate fuel differences for all flights for sample period and determine results across all 15 sample days. These results are described in the following sections.

Section 4

Discussion of Results

4.1 Characterization of the Sample Day Flights

Across the 15 sample days in the five months from October 1998 to December 1999, the flights through WATRS are characterized in the following tables and discussed below.

Looking at the aircraft counts separated by type of user (Table 4-1), the population of the flights for all sample days was 49% U.S. Carrier, 43% Foreign Carrier, 5% General Aviation (GA), and 3% Military. There was some variation in the population across the samples, but it was not significant (+/- 1-2% in most cases). The biggest variations were seasonal shifts in the GA flights, with more flights in the winter and fewer flights in the summer. The three-day total aircraft count for October 1999 was apparently low, even though the proportion of carriers and aircraft types was consistent with other month samples.

Examining which flights were flown on RVSM capable airframes (Table 4-2), 91% of all flights were RVSM capable, while 95% of U.S. Carrier and 96% of Foreign Carrier flights were RVSM capable. Note that "RVSM capable" was defined as those having approved RVSM service bulletins, as outlined in Table 2-1. U.S. and Foreign Carriers made consistent use of RVSM capable aircraft during the sample periods, with some indication of a trend toward using more RVSM capable aircraft as time passed. Military and GA use of RVSM capable aircraft was much lower and much less consistent over the sample period, as both types of user made much less predictable use of airframe types.

For the benefit of the analysis, the number of flights that make use of the Top 12 aircraft types was also examined (refer to list on Table 2-1, and to Table 4-3 for results). Note that Fuel Burn Tables were developed for the Top 12 aircraft types, and a fuel burn Rule of Thumb was used for the other types. Eighty eight percent of all flights were of the Top 12 aircraft types, while 99% of U.S. Carrier flights and 91% of Foreign Carrier flights were of the Top 12 aircraft types. U.S. and Foreign Carriers made consistent use of the Top 12 aircraft types during the sample periods, while Military and GA use of the Top 12 aircraft types was much lower and much less consistent over the sample period.

Table 4-1. Aircraft Counts (3 sample days/months)

	Oct 1998		Mar 1999		Jul 1999		Oct 1999		Dec 1999		TOTAL 1999		TOTAL ALL	
	flights	%	flights	%	flights	%	flights	%	flights	%	flights	%	flights	%
U.S. Carrier	459	47.1	532	47.6	524	49.8	425	49.8	503	49.5	1984	49.1	2443	**48.7**
Foreign Carrier	443	45.5	480	42.9	468	44.4	356	41.7	423	41.6	1727	42.7	2170	**43.3**
Military	31	3.2	35	3.1	30	2.8	36	4.2	31	3.0	132	3.3	163	**3.2**
General Aviation	41	4.2	71	6.4	31	2.9	37	4.3	60	5.9	199	4.9	240	**4.8**
Total Aircraft	974		1118		1053		854		1017		4042		**5016**	

Table 4-2. RVSM Capable Aircraft

		Oct 1998		Mar 1999		Jul 1999		Oct 1999		Dec 1999		TOTAL 1999		TOTAL ALL	
		flights	%	flights	%	flights	%	flights	%	flights	%	flights	%	flights	%
U.S. Carrier	RVSM	418	91.1	497	93.4	509	97.1	411	96.7	486	96.6	1903	95.9	2321	**95.0**
	non	41		35		15		14		17		81		122	
Foreign Carrier	RVSM	415	93.7	468	97.5	451	96.4	343	96.3	411	97.2	1673	96.9	2088	**96.2**
	non	28		12		17		13		12		54		82	
Military	RVSM	14	45.2	14	40.0	12	40.0	13	36.1	12	38.7	51	38.6	65	**39.9**
	non	17		21		18		23		19		81		98	
General Aviation	RVSM	7	17.1	39	54.9	17	54.8	18	48.6	17	28.3	91	45.7	98	**40.8**
	non	34		32		14		19		43		108		142	
Total Aircraft		974		1118		1053		854		1017		4042		5016	
										Total	**rvsm**	**3718**	**92.0**	**4572**	**91.1**
											non	**324**	**8.0**	**444**	**8.9**

Table 4-3. Top 12 Aircraft Types

		Oct 1998		Mar 1999		Jul 1999		Oct 1999		Dec 1999		TOTAL 1999		TOTAL ALL	
		flights	%	flights	%	flights	%	flights	%	flights	%	flights	%	flights	%
U.S. Carrier	Top 12	451	98.3	524	98.5	524	100.0	424	99.8	493	98.0	1965	99.0	2416	**98.9**
	Other	8		8		0		1		10		19		27	
Foreign Carrier	Top 12	402	90.7	441	91.9	417	89.1	322	90.4	388	91.7	1568	90.8	1970	**90.8**
	Other	41		39		51		34		35		159		200	
Military	Top 12	8	25.8	1	2.9	6	20.0	3	8.3	3	9.7	13	9.8	21	**12.9**
	Other	23		34		24		33		28		119		142	
General Aviation	Top 12	0	0.0	3	4.2	2	6.5	1	2.7	2	3.3	8	4.0	8	**3.3**
	Other	41		68		29		36		58		191		232	
Total Aircraft		974		1118		1053		854		1017		4042		5016	
												Total Top 12		**4415**	**88.0**
												other		**601**	**12.0**

4.2 Optimal Fuel Burn Results

The results of the analysis of the sample day flights adjusted for optimum fuel burn are shown on Table 4-4, and are discussed here.

All flights from the sample days were permitted to fly through WATRS on the same flight-planned route, but each flight entered WATRS at its optimum altitude and stayed at that altitude for the duration of its time in WATRS. Optimum altitude was determined by looking up the best fuel burn altitude for the Top 12 aircraft types, and by analyzing the preferred altitude flown for the other aircraft types.

For the Top 12 aircraft types, fuel burn for the optimum altitude was then calculated and compared to the fuel burn for the altitude actually flown in the sample data, to obtain the delta fuel burn. The "% saved" was then calculated for the delta fuel as compared to the fuel expended for the flight flown at actual altitude. An overall savings of 1.3% of fuel can be realized if all flights were permitted to fly at optimum altitude. The vast majority of fuel savings was accomplished by the U.S. and Foreign Carriers, largely because they accounted for 99 percent of the Top 12 aircraft type flights. Fuel savings for these RVSM capable flights ranged from .9 to 1.9%, while the fuel penalty for non-RVSM capable flight ranged from -2.2 to -5.4%, depending on the sample month.

Several points should be noted about the construction of the Fuel Burn Table for the Top 12 aircraft types, with the Jeppesen Flight Planning system.

38) Although there was a wide variation in the airframe models, typical airframes of each type were used. Typical routes were also used to develop the Fuel Burn table.

39) The fuel burn rate for those altitudes close to the optimum altitude tended to become very similar to the fuel burn rate of the optimum altitude, with many cases of the identical fuel burn rate for 1-3 thousand foot altitudes below the optimum. If the same fuel burn was available at several altitudes, then the highest altitude was chosen as the optimum.

40) The Jeppesen model often would not permit a flight to be planned at altitudes higher than the optimum, presuming insufficient fuel for the flight. Any flights found at these altitudes were assumed to be flying at their optimum altitudes and permitted to remain there. The Jeppesen model also gave insufficient fuel results for flights at too low an altitude to make the flight; these were also accommodated in the Fuel Burn Tables.

Table 4-4. Optimum Fuel Savings in Pounds

		Oct 1998		Mar 1999		Jul 1999		Oct 1999		Dec 1999		TOTAL 1999		TOTAL ALL	
		delta fuel	% saved	delta fuel	% saved	delta fuel	% saved	delta fuel	% saved	delta fuel	% saved	delta fuel	% saved	delta fuel	% saved
Top 12 A/C Types															
U.S. Carrier	RVSM	95298	1.5%	144354	1.9%	129744	1.6%	86590	1.5%	131700	1.8%				
	non	-22050	-4.0%	-19680	-3.8%	-7300	-3.0%	-7200	-3.9%	-5500	-2.7%				
	total	73248	1.1%	124674	1.5%	122444	1.5%	79390	1.3%	126200	1.7%	452708	1.5%	525956	1.4%
Foreign Carrier	RVSM	120124	1.3%	103945	1.3%	110872	1.2%	69073	1.1%	75576	0.9%				
	non	-3450	-3.2%	-1600	-4.4%	-4400	-4.2%	-2550	-5.4%	-2400	-2.2%				
	total	116674	1.3%	102345	1.3%	106472	1.2%	66523	1.1%	73176	0.8%	348516	1.1%	465190	1.1%
Military	RVSM	6600	2.8%	0	0.0%	700	1.0%	0	0.0%	-350	-1.6%				
	non	0	0.0%	0	0.0%	-250	-0.6%	0	0.0%	-250	-0.9%				
	total	6600	2.8%	0	0.0%	450	0.4%	0	0.0%	-600	-1.2%	-150	-0.1%	6450	1.0%
General Aviation	RVSM	0	0.0%	800	2.8%	0	0.0%	0	0.0%	0	0.0%				
	non	0	0.0%	-1200	-7.0%	0	0.0%	0	0.0%	0	0.0%				
	total	0	0.0%	-400	-0.9%	0	0.0%	0	0.0%	0	0.0%	-400	-0.3%	-400	-0.3%
Fuel Savings		196522	1.2%	226619	1.4%	229366	1.3%	145913	1.2%	198776	1.2%	800674	1.3%	997196	1.3%
Other A/C Types															
U.S. Carrier	RVSM	8832		8448		0		0		3904					
	non	0		0		0		0		-768					
	total	8832		8448		0		0		3136		11584		20416	
Foreign Carrier	RVSM	10560		11328		22636.8		11136		14784					
	non	-20160		-5568		-6144		-8832		-7296					
	total	-9600		5760		16492.8		2304		7488		32044.8		22444.8	
Military	RVSM	2944		3072		4224		3712		4864					
	non	-5632		-1536		-4672		-5120		-1920					

	total	-2688	1536	-448	-1408	2944	2624	-64
General Aviation	RVSM	5568	19712	1920	5120	5632		
	non	-20608	-21568	-10880	-11520	-21760		
	total	-15040	-1856	-8960	-6400	-16128	-33344	-48384
Fuel Savings		-18496	13888	7084.8	-5504	-2560	12908.8	-5587.2

Table 4-4. Optimum Fuel Savings in Pounds (Concluded)

		Oct 1998 delta fuel % saved	Mar 1999 delta fuel % saved	Jul 1999 delta fuel % saved	Oct 1999 delta fuel % saved	Dec 1999 delta fuel % saved	**TOTAL 1999 delta fuel % saved**	**TOTAL ALL delta fuel % saved**
Total Fuel Savings								
Total Fuel Savings	RVSM	249926	291659	270096.8	175631	236110	**973496.8**	**1223423**
Flights	RVSM	854	1018	989	785	926	**3718**	**4572**
Average Fuel Savings per Flight	RVSM	292.7 lbs	286.5 lbs	273.1 lbs	223.7 lbs	255.0 lbs	**261.8 lbs**	**267.6 lbs**
Total Fuel Savings	non	-71900	-51152	-33646	-35222	-39894	**-159914**	**-231814**
Flights	non	120	100	64	69	91	**324**	**444**
Average Fuel Savings per Flight	non	-599.2 lbs	-511.5 lbs	-525.7 lbs	-510.5 lbs	-438.4 lbs	**-493.6 lbs**	**-522.1 lbs**
Total Fuel Savings (RVSM and non)		178026	240507	236450.8	140409	196216	**813582.8**	**991608.8**
Total Flights		974	1118	1053	854	1017	**4042**	**5016**
Average Fuel Savings per Flight		182.8 lbs	215.1 lbs	224.5 lbs	164.4 lbs	192.9 lbs	**201.3 lbs**	**197.7 lbs**

The delta fuel burn for the "Other" aircraft types (those not of the Top 12) was calculated directly from the Rule of Thumb. Since this calculation provided only an estimate of the fuel burn savings or penalty (delta fuel), and not of the actual or optimal fuel expended, the savings percentage could not be calculated, since it is a ratio of delta fuel burn to actual fuel burn. However, since the other aircraft types only accounted for 12 percent of the flights in all the sample days, these results were less influential on the overall fuel savings. Note that there were more non-RVSM capable flights in the other aircraft types, thus non-RVSM flights had a bigger influence in this segment.

The RVSM capable flight fuel savings and the non-RVSM capable flight fuel penalties are summarized at the bottom of the table. The RVSM capable flights can save an average of 268 pounds of fuel while they were in WATRS, while the non-RVSM capable flights expended 522 pounds more fuel on average while they were in WATRS. Overall, the rules for WATRS RVSM Phase II provided an average savings of 198 pounds of fuel per flight, if the RVSM capable aircraft were permitted to fly at their optimum altitude and the non-RVSM capable aircraft were directed to fly below FL280 or above FL410.

The impact of step climbs and new routes was assessed to determine the magnitude of their effect.

41) Step climbs that were actually taken in the sample data were examined to see if they would affect the results of the optimum fuel savings. Approximately 11 percent of the flights took one or more steps in altitude while in WATRS. If the flights that took step climbs had their step climb included in the optimum altitude flight profile, the overall impact would be less than a .05 percent reduction in overall fuel savings, so the impact was considered negligible.

42) New routes, and their impact on routes loads and permitting flights to be assigned their optimum altitudes, were examined on a preliminary basis. Two samples were B891 and A705 that were implemented in January 2000. B891 was an extension of an old route (UB891) entering NY WATRS at the GRANN waypoint and cutting across some relatively unused WATRS routes. A705 entered NY WATRS from MILLE waypoint and cut across several major north-south routes including the highly used A300. Preliminary analysis of the new routes showed little or no impact to the fuel benefits, based on expected loads on the routes.

Two modifications were made to these optimum altitude calculations, to provide for a more realistic profile of flights flown through WATRS. The results of these analyses are described in Section 4.3.

4.3 "Altitude for Direction" Fuel Burn Results

Once the optimal altitude for each flight was determined and the delta fuel savings were calculated, a set of altitude-for-direction rules, or "rules of the road" was imposed on those optimized flights. The draft rules used in this analysis were composed with the assistance of ATP-130, and are listed in Section 2.3. The results are tabulated on Table 4-5.

The rules caused north/south bound flights to be shifted in altitude by +/- 1000 feet to comply, while the east/west bound flights were moved up 1000 or down 2000 feet to comply with the stated timeframes, otherwise flights were left at their optimum altitudes. Thirty seven percent of the flights were moved in altitude to comply with "altitude for direction" rules. The effect of these changes was only a slight decrease in the fuel burn savings, overall from 1.3 to 1.2%. The reason for such a slight impact on savings was that the Jeppesen fuel burn table results for many of the Top 12 aircraft types were very similar within 1000-3000 feet of the optimum altitude (see discussion above). Since the "altitude for direction" rules involved only 1000-2000 foot altitude changes, the change in the fuel burn savings from the optimum was not significantly affected. Alternate sets of "altitude for direction" rules would be expected to have similar impacts on fuel burn savings, provided they require only 1000-2000 foot changes in altitude from the optimum.

The majority of the fuel burn savings was attributable to flights in "pushes" that were predominantly forced to enter WATRS airspace at a lower than optimum altitude. Because of the availability of more altitudes with RVSM and an "accordian" effect of the aircraft above moving slightly closer to their preferred altitudes, the flights entering low were able to enter at a much more efficient altitude.

The savings noted on the "Altitude for Direction" table are similar to those on the Optimum Table, with slight changes to the "other" aircraft types, and to the distribution of the RVSM fuel savings and non-RVSM fuel penalties. Overall, the rules for WATRS RVSM Phase II, with flight altitudes adjusted from optimum to "altitude for direction" rules, would provide an average savings of 190 pounds of fuel per flight.

Table 4-5. "Altitude for Direction" Results – Fuel Savings in Pounds

		Oct 1998 delta fuel	Oct 1998 % saved	Mar 1999 delta fuel	Mar 1999 % saved	Jul 1999 delta fuel	Jul 1999 % saved	Oct 1999 Delta Fuel	Oct 1999 % saved	Dec 1999 delta fuel	Dec 1999 % saved	TOTAL 1999 delta fuel	TOTAL 1999 % saved	TOTAL ALL delta fuel	TOTAL ALL % saved
Top 12 A/C Types															
U.S. Carrier	RVSM	93878	1.5%	142054	1.9%	129444	1.6%	85990	1.5%	130500	1.8%				
	non	-26710	-4.8%	-23350	-4.5%	-9900	-4.0%	-9400	-5.1%	-8300	-4.0%				
	total	67168	1.0%	118704	1.5%	119544	1.5%	76590	1.3%	122200	1.6%	437038	1.5%	504206	1.4%
Foreign Carrier	RVSM	92520	1.0%	107495	1.3%	115172	1.3%	73473	1.2%	77776	0.9%				
	non	-4650	-4.3%	-1900	-5.2%	-5400	-5.1%	-3150	-6.6%	-2900	-2.6%				
	total	87870	1.0%	105595	1.3%	109772	1.2%	70323	1.1%	74876	0.8%	360566	1.1%	448436	1.1%
Military	RVSM	6000	2.5%	0	0.0%	900	1.3%	0	0.0%	-350	-1.6%				
	non	0	0.0%	0	0.0%	-250	-0.6%	0	0.0%	-250	-0.9%				
	total	6000	2.5%	0	0.0%	650	0.6%	0	0.0%	-600	-1.2%	50	0.0%	6050	1.0%
General Aviation	RVSM	0	0.0%	800	2.8%	0	0.0%	0	0.0%	0	0.0%				
	non	0	0.0%	-1200	-7.0%	0	0.0%	0	0.0%	0	0.0%				
	total	0	0.0%	-400	-0.9%	0	0.0%	0	0.0%	0	0.0%	-400	-0.3%	-400	-0.3%
Fuel Savings		161038	1.0%	223899	1.4%	229966	1.3%	146913	1.2%	196476	1.2%	797254	1.3%	958292	1.2%
Other A/C Types															
U.S. Carrier	RVSM	8832		8448		0		0		3904					
	non	0		0		0		0		-768					
	total	8832		8448		0		0		3136		11584		20416	
Foregin Carrier	RVSM	10560		11328		22636.8		11136		14784					
	non	-20160		-5568		-6144		-8832		-7296					
	total	-9600		5760		16492.8		2304		7488		32044.8		22444.8	
Military	RVSM	2944		3072		4224		3712		4864					
	non	-5632		-1536		-4672		-5120		-1920					
	total	2688		1536		448		1408		2944		2624		64	

General Aviation	RVSM	5568	19712	1920	5120	5632		
	non	- 20608	- 21568	-10880	- 11520	- 21760		
	total	- 15040	-1856	-8960	-6400	- 16128	-33344	-48384
Fuel Savings		- 18496	13888	7084.8	-5504	-2560	12908.8	-5587.2

Table 4-5. "Altitude for Direction" Results – Fuel Savings in Pounds (Concluded)

		Oct 1998 delta fuel % saved	Mar 1999 delta fuel % saved	Jul 1999 delta fuel % saved	Oct 1999 delta fuel % saved	Dec 1999 Delta fuel % saved	TOTAL 1999 delta fuel % saved	TOTAL ALL delta fuel % saved
Total Fuel Savings								
Fuel Savings	RVSM	22030 2	29290 9	274296. 8	17943 1	23711 0	983746. 8	1204049
Flights	RVSM	854	1018	989	785	926	3718	4572
Average Fuel Savings per Flight	RVSM	258.0 lbs	287.7 lbs	277.3 lbs	228.6 lbs	256.1 lbs	264.6 lbs	263.4 lbs
Fuel Savings	non	- 77760	- 55122	-37246	- 38022	- 43194	-173584	-251344
Flights	non	120	100	64	69	91	324	444
Average Fuel Savings per Flight	non	- lbs 648.0	- lbs 551.2	-582.0 lbs	- lbs 551.0	- lbs 474.7	-535.8 lbs	-566.1 lbs
Total Fuel Savings (RVSM and non)		14254 2	23778 7	237050. 8	14140 9	19391 6	810162. 8	952704. 8
Total Flights		974	1118	1053	854	1017	4042	5016
Average Fuel Savings per Flight		146.3 lbs	212.7 lbs	225.1 lbs	165.6 lbs	190.7 lbs	200.4 lbs	189.9 lbs

4.4 Operational Feasibility Fuel Burn Results

Once the flights were adjusted for the "altitude for direction" rules, they were inspected for separation at the entry fixes to WATRS and at the major WATRS internal intersections. The results are tabulated on Table 4-6.

The separation rules applied in this analysis were 10 minutes in-trail, 15 minutes crossing, and 0 minutes diverging. If two flights were found to be too close to each other at the fixes, one of the flights was given a different altitude to avoid this loss of separation. In this operational feasibility check, 6.6 percent of the aircraft were found to be within the separation standards, and were typically moved up 1000 or down 3000 feet in altitude (to stay at the correct altitude for direction). As with the "altitude for direction" adjustments, the overall fuel burn savings were only slightly affected; in fact, several flights were moved to a better altitude, so the overall results were still 1.2 percent fuel savings.

Alternate separation rules can be applied in this operational feasibility check, to test the sensitivity of analysis results to the separation rules. A preliminary investigation was made into the number of pairs of flights across all days that were separated by 10, 12, 15, and 17 minutes at key fixes. As one might expect, for each larger unit of time, there were more aircraft pairs within that separation. However, for each time separation, looking at the flights "before RVSM" and comparing them to flights "after RVSM", there were decreases in the number of flights at entry fixes, and increases in the number of flights at crossing fixes. In no case was the number of flights involved very large (less than 9 percent). In any event, as in the "altitude for direction" analysis, if the change in altitude to solve separation encounters was limited to only 1000-2000 foot altitude changes, fuel burn savings would not be significantly affected.

Again, the savings noted on the "Operational Feasibility" table are similar to those on the "Altitude for Direction" and Optimum Tables, with slight changes to the "other" aircraft types, and to the distribution of the RVSM fuel savings and non-RVSM fuel penalties. Overall, the rules for WATRS RVSM Phase II, with flight altitudes adjusted from optimum to "altitude for direction" and considering operational feasibility, would provide an average savings of 188 pounds of fuel per flight.

Table 4-6. Operational Feasibility Results – Fuel Savings in Pounds

		Oct 1998 delta fuel	Oct 1998 % saved	Mar 1999 delta fuel	Mar 1999 % saved	Jul 1999 delta fuel	Jul 1999 % saved	Oct 1999 delta fuel	Oct 1999 % saved	Dec 1999 Delta Fuel	Dec 1999 % saved	TOTAL 1999 delta fuel	TOTAL 1999 % saved	TOTAL ALL delta fuel	TOTAL ALL % saved
Top 12 A/C Types															
U.S. Carrier	RVSM	92628	1.5%	139970	1.9%	128175	1.6%	83590	1.4%	128401	1.8%				
	non	-27510	-5.0%	-24850	-4.8%	-10600	-4.3%	-10100	-5.5%	-8300	-4.0%				
	total	65118	1.0%	115120	1.4%	117575	1.4%	73490	1.2%	120101	1.6%	426286	1.4%	491404	1.3%
Foreign Carrier	RVSM	91270	1.0%	122527	1.5%	113317	1.2%	71435	1.1%	74226	0.8%				
	non	-4650	-4.3%	-1900	-5.2%	-5400	-5.1%	-3150	-6.6%	-2900	-2.6%				
	total	86620	0.9%	120627	1.5%	107917	1.2%	68285	1.1%	71326	0.8%	368155	1.2%	454775	1.1%
Military	RVSM	6000	2.5%	0	0.0%	900	1.3%	0	0.0%	-350	-1.6%				
	non	0	0.0%	0	0.0%	-250	-0.6%	0	0.0%	-250	-0.9%				
	total	6000	2.5%	0	0.0%	650	0.6%	0	0.0%	-600	-1.2%	50	0.0%	6050	1.0%
General Aviation	RVSM	0	0.0%	800	2.8%	0	0.0%	0	0.0%	0	0.0%				
	non	0	0.0%	-1200	-7.0%	0	0.0%	0	0.0%	0	0.0%				
	total	0	0.0%	-400	-0.9%	0	0.0%	0	0.0%	0	0.0%	-400	-0.3%	-400	-0.3%
Fuel Savings		157738	1.0%	235347	1.4%	226142	1.3%	141775	1.1%	190827	1.2%	794091	1.3%	951829	1.2%
Other A/C Types															
U.S. Carrier	RVSM	9216		7680		0		0		3904					
	non	0		0		0		0		-768					
	total	9216		7680		0		0		3136		10816		20032	
Foregin Carrier	RVSM	10944		11136		22636.8		11136		14400					
	non	-20160		-5568		-6144		-8832		-7296					
	total	-9216		5568		16492.8		2304		7104		31468.8		22252.8	
Military	RVSM	2944		2816		4224		1984		4864					
	non	-5440		-1536		-4672		-5120		-1920					

	total	-2496	1280	-448	-3136	2944	640	-1856
General Aviation	RVSM	5376	19712	1920	5120	5632		
	non	- 20608	- 19904	-10880	- 11520	- 21760		
	total	- 15232	-192	-8960	-6400	- 16128	-31680	-46912
Fuel Savings		- 17728	14336	7084.8	-7232	-2944	11244.8	-6483.2

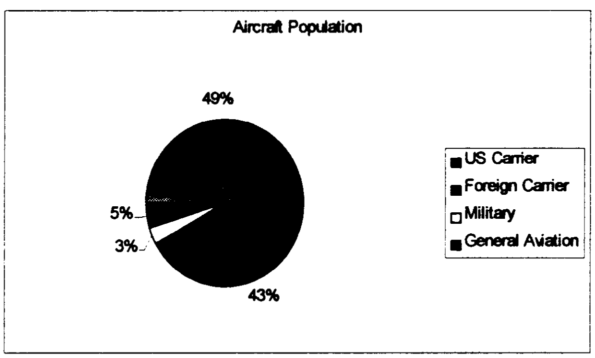
Table 4-6. Operational Feasibility Results – Fuel Savings in Pounds (Concluded)

		Oct 1998 delta fuel % saved	Mar 1999 delta fuel % saved	Jul 1999 delta fuel % saved	Oct 1999 delta fuel % saved	Dec 1999 delta fuel % saved	TOTAL 1999 delta fuel % saved	TOTAL ALL delta fuel % saved
Total Fuel Savings								
Fuel Savings	RVSM	21837 8	30464 1	271172. 8	17326 5	23107 7	980155. 8	1198534
Flights	RVSM	854	1018	989	785	926	3718	4572
Average Fuel Savings per Flight	RVSM	255.7 lbs	299.3 lbs	274.2 lbs	220.7 lbs	249.5 lbs	263.6 lbs	262.1 lbs
Fuel Savings	non	- 78368	- 54958	-37946	- 38722	- 43194	-174820	-253188
Flights	non	120	100	64	69	91	324	444
Average Fuel Savings per Flight	non	- 653.1 lbs	- 549.6 lbs	-592.9 lbs	- 561.2 lbs	- 474.7 lbs	-539.6 lbs	-570.2 lbs
Total Fuel Savings (RVSM and non)		14001 0	24968 3	233226. 8	13454 3	18788 3	805335. 8	945345. 8
Total Flights		974	1118	1053	854	1017	4042	5016
Average Fuel Savings per Flight		143.7 lbs	223.3 lbs	221.5 lbs	157.5 lbs	184.7 lbs	199.2 lbs	188.5 lbs

Section 5

Summary of Results

For the WATRS RVSM Phase II benefits analysis, 15 sample days were studied across all seasons in the October 1998 to December 1999 timeframe, with the aircraft population shown in Figure 5-1. The benefits of RVSM were analyzed by estimating the fuel burn savings of all RVSM capable aircraft flying at their optimum altitude, and the fuel burn penalty of all non-RVSM capable aircraft flying at or below FL280, or at or above FL420. Overall, 91 percent of the aircraft were RVSM capable; the break-out by flight types is shown in Figure 5-1. For analysis purposes, fuel burn tables were developed for the Top 12 airframes, most of which were RVSM capable, though a couple (some B727 and DC8) were not. Overall, 88 percent of sample flights were of the Top 12 airframe types; break-out by flight types is also shown in Figure 5-1. A fuel burn "Rule of Thumb" was used for all other airframes. The Optimal Fuel Savings were calculated for all RVSM capable aircraft flying at their optimum altitudes, then "Altitude for Direction" and "Operational Feasibility" checks were made to impose realism on the optimal results.



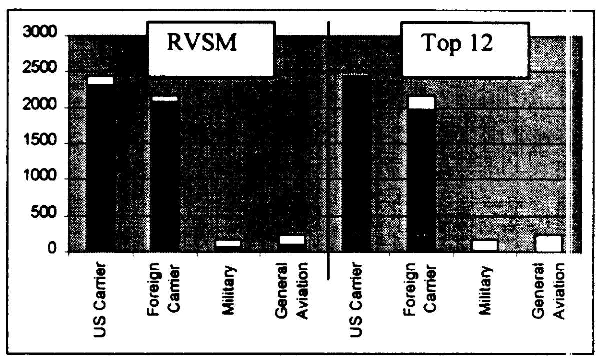


Figure 5-1. Polpulation, RVSM Capability and Top 12 Aircraft Types

U.S. Carriers. Forty nine percent of the flights over WATRS were flown by U.S. carriers. Of these, 95% were flown with RVSM capable airframes (had approved RVSM service bulletins), while 5% were flown with non-RVSM capable airframes. The Top 12 airframes accounted for 99% of the U.S. carriers (fuel burn tables used for analysis); only 1% required use of the "Rule of Thumb". The Top 12 aircraft flights posted a fuel burn savings of about 1.3-1.4%, which was consistent across the sample days.

Foreign Carriers. Forty three percent of the flights over WATRS were flown by foreign carriers. Of these, 96% were flown with RVSM capable airframes (had approved RVSM service bulletins), while 4% were flown with non-RVSM capable airframes. The Top 12 airframes accounted for 91% of the foreign carriers (fuel burn tables used for analysis); 9% required use of the "Rule of Thumb". The Top 12 aircraft flights posted a fuel burn savings of about 1.1%, which was consistent across the sample days.

Military. Three percent of the flights over WATRS were flown by Military flights. Of these, 40% were flown with RVSM capable airframes (had approved RVSM service bulletins), while 60% were flown with non-RVSM capable airframes. The Top 12 airframes accounted for only 13% of the Military flights (fuel burn tables used for analysis); 87% required use of the "Rule of Thumb". The Top 12 aircraft flights posted a fuel burn savings of about 1.0% which varied across the sample days, due largely to the significant variations in military flight schedules.

General Aviation. Five percent of the flights over WATRS were flown by GA flights. Of these, 41% were flown with RVSM capable airframes (had approved RVSM service bulletins), while 59% were flown with non-RVSM capable airframes. The Top 12 airframes accounted for only 3% of the GA flights (fuel burn tables used for analysis); 97% required use of the "Rule of Thumb". The few Top 12 aircraft flights posted a fuel burn savings of about -0.3%, which varied across the sample days, due largely to the significant variations in GA flight schedules.

Overall Results. Overall, 91 percent of the flights through WATRS were flown with RVSM capable aircraft. The Top 12 aircraft types accounted for 88 percent of the flights. The analysis revealed a net 1.3% overall fuel savings for these Top 12 airframes, assuming they were permitted to fly at their optimum altitudes. This savings was reduced slightly to 1.2% when "Altitude for Direction" and "Operational Feasibility" rules were imposed.

An overall fuel penalty of 5500 - 6500 pounds was estimated for all of the "other" aircraft types (those not of the Top 12, which accounted for 12 percent of all flights), for which the "Rule of Thumb" rule was applied. It should be noted that this penalty is less than 0.5 percent of the fuel savings attributed to the aircraft within the Top 12 aircraft types.

Therefore, a net fuel burn savings of approximately 1.2% - 1.3% was estimated for all flights (i.e., U.S., Foreign, Military, GA) in the WATRS area.

An average savings of 188 pounds of fuel was estimated on a per flight basis. It should be noted that this can vary greatly by airframe. The average savings is based on the analysis result that RVSM flights would save an average of 262 pounds of fuel, and non-RVSM flights would expend an additional average of 570 pounds of fuel.

Section 6

Additional Analysis

Additional analyses can be performed, based on the preliminary results for the baseline analysis above. These analyses would examine the impacts to flights, not just of optimizing altitude with RVSM, but also of redistributing traffic to alternate routes.

- **Alternative "Altitude for Direction" Rules".** Other sets of "altitudes for direction" rules would be developed, in coordination with ATP-130, ZNY, and the CETF. These "rules of the road" would be applied to the optimum analysis results obtained above and the sensitivity of the results to these rule variations would be determined.

- **Additional Aircraft Types.** For this analysis, all of the Top 12 aircraft types were carrier sized. To account for general aviation better, one or more aircraft types that were used by GA could be added to the fuel burn model. In examining the sample data, there were a number of GLF3, GLF4, GLF5, and GULFs, as well as G159, CL60, and FA50s (see Table 6-1); any of these could be selected to represent the GA aircraft types. The GAs tend to use the north/south routes and travel extensively to Bermuda. For this extended analysis, a series of additional Jeppesen runs would be needed to get the data at altitudes, then the analysis (optimum and "direction for altitude") for the GAs would be re-run and the results would be blended back into the rest of the analysis to recheck operational feasibility. At this time, CAASD has been directed to develop fuel burn tables for the G4 and G159, in order to provide more detailed data for the NPR.

- **Traffic Redistribution.** An attempt would be made to examine the effect of the redistribution of traffic from A637 to B646, and A700 to A699. A637 and A700 are two overflow tracks for the preferred tracks of B646 and A699, when they are overloaded. With RVSM, the overloading problem should be minimized, so the traffic can be moved back to the preferred tracks. Because the route segments for the preferred and overflow tracks are approximately the same within the WATRS region, the expected user benefit would be realized in the time and fuel saved in reaching these routes. Since this occurs outside of the WATRS region, the data would be examined to determine the common points prior to entry to WATRS as well as subsequent to exit from WATRS. A standard fuel/time estimate (based on flight origin) would be developed as the benefit for shifting tracks, and would be added to those flights.

Table 6-1. GA Aircraft Types and Counts from 15 Day Sample

AC95	2	CL60	14	G5	2	L29B	1
ASTR	1	CL64	1	GLF1	1	LJ35	11
B350	1	DA50	1	GLF2	16	LJ36	2
B721	6	DA90	1	GLF3	12	LJ55	7
B727	1	F2TH	1	GLF4	26	LJ60	4
B733	1	F900	5	GLF5	6	LR35	3
BE90	1	FA10	2	GULF	15	LR60	1
C525	1	FA20	4	H25	2	SBR1	1
C550	1	FA50	13	H25A	3	SBR6	1
C560	5	FJ10	1	H25B	9	WW24	7
C650	4	G159	21	H25C	9		
C750	5	G4	7	HS25	1		

Glossary

AFS	Flight Standards Service
ARTCC	Air Route Traffic Control Center
ATP	Air Traffic Rules and Procedures Service
CAASD	Center for Advanced Aviation System Development
CERAP	Combined Center Radar Approach Control
CETF	Capacity-Enhancement Task Force
ETMS	Enhanced Traffic Management System
FACSFAC	Fleet Area Control and Surveillance Facility
FIR	Flight Information Region
FL	Flight Level
GA	General Aviation
ICAO	International Civil Aviation Organization
IMG	Implementation Management Group
MNPS	Minimum Navigation Performance Specification
NAT	North Atlantic
NICE	North Atlantic Implementation Management Group Cost/Effectiveness
NPR	Notice for Proposed Rulemaking
ODAPS	Oceanic Display and Planning System
ODR	Oceanic Data Repository
RVSM	Reduced Vertical Separation Minima
WATRS	Western Atlantic Track System
ZNY	New York Center