Final Report
For
Domestic Reduced Vertical Separation Minima (DRVSM)
Third Simulation

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Prepared for:

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1. INTRODUCTION

1.1 Background

Reduced Vertical Separation Minimum (RVSM) is an ICAO-approved concept that reduces the vertical separation standard from 2000 feet to 1000 feet between flight level (FL) 290 and FL410. RVSM adds six flight levels between FL290 and FL410, thereby increasing airspace throughput and allowing more flexibility for controllers to grant user preferred altitudes. RVSM has been implemented in the North Atlantic and Pacific oceanic airspace, and was implemented in domestic European airspace in January 2002. Domestic RVSM (DRVSM) is a high priority for the FAA's Operational Evolution Plan (OEP); however, the impact on en route controllers in high-density domestic U.S. airspace needs to be understood.

Under the auspices of the Air Traffic Planning and Procedures Program (ATP), a series of human-in-the-loop (HITL) simulations have been conducted to investigate the operational impacts on en route controllers of implementing RVSM in domestic U.S. airspace. The first of the series of HITL simulations took place October 24 – 30, 2001, at the William J. Hughes Technical Center (WJHTC) Display System Facility (DSF). This first simulation focused primarily on identifying and understanding the impacts of different DRVSM altitude bands on en route controllers. The second DRVSM simulation took place June 3 - 7, 2002, and focused on understanding the impact of non-RVSM-approved aircraft under heavy traffic conditions. The third DRVSM simulation occurred June 9 – 12, 2003. The primary focus of this simulation was air traffic procedures and controller training.

1.2 Scope of the Report

This Final Report provides the results of the third DRVSM simulation. Data collection for this simulation consisted primarily of subjective data in the form of controller responses to questionnaires and controller comments during debrief sessions following each simulation run.

1.3 Document Organization

This document is organized in six sections and one appendix. Section 2 provides an overview of the simulation structure, environment, and conduct. The results of the simulation are provided in Sections 3 through 5, and Section 6 provides conclusions. Appendix A provides the draft phraseology used during the simulation.

2. SIMULATION OVERVIEW

2.1 Objectives

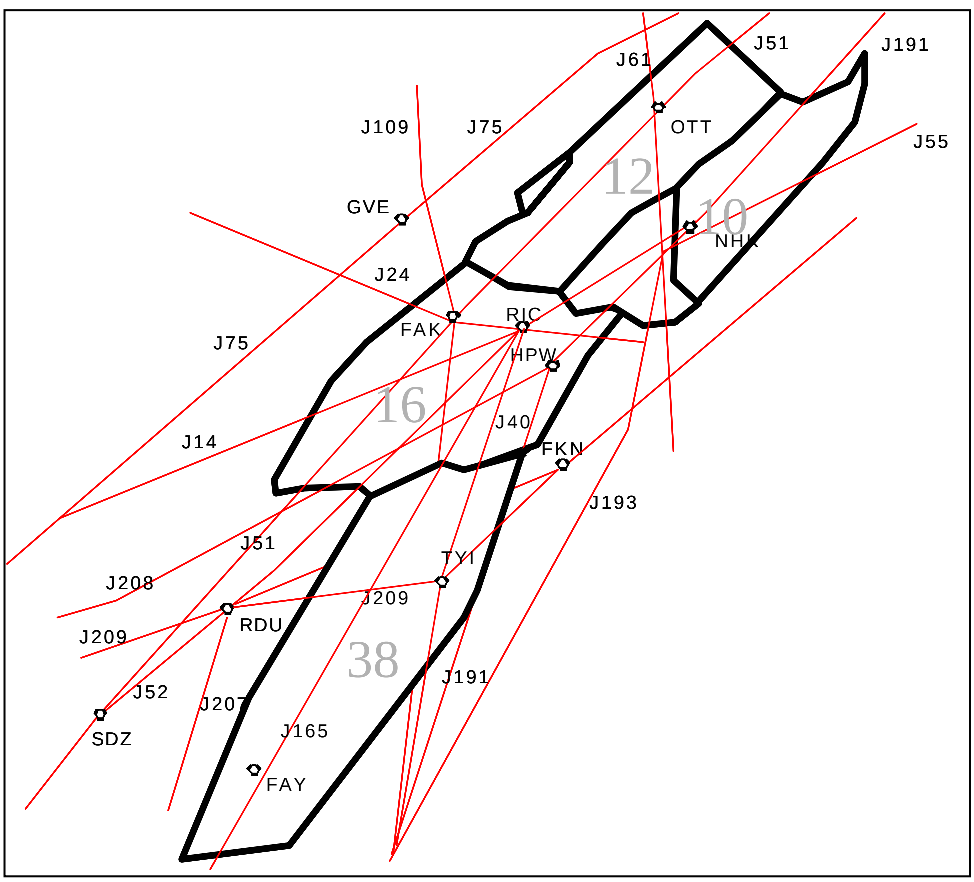
The objectives for the third DRVSM simulation were to:

1. Assess DRVSM procedures;
2. Gain insight for the development of DRVSM training plans; and
3. Assess the impacts of using the new altitudes tactically in a conventional vertical separation (CVS) environment.

2.2 Airspace

This third DRVSM simulation was designed as a real-time, high fidelity, HITL, en route simulation. The simulated airspace was based on four adjacent sectors in Washington Air Route Traffic Control Center (ZDC). ZDC sectors 10 (Bay), 12 (Brooke), 16 (Hopewell), and 38 (Tar River) had the appropriate characteristics for this study. Sector 10, combined at Sector 12 for the purposes of the simulation, encompasses FL240 and above. Sector 16 (Hopewell) is a high altitude sector whose area of responsibility includes FL280 and above. Sector 38 (Tar River High) is also a high altitude sector (FL240 and above). Figure 2-1 provides a depiction of the airspace used.

FIGURE 2-1. Simulated ZDC Airspace



2.3 Scenarios

The traffic scenarios provided a range of traffic density and level of complexity. Four distinct traffic scenarios were developed from flight plans extracted from data analysis and reduction tool (DART) runs of ZDC system analysis and recording (SAR) tapes. The data allowed for the realistic representation of sector boundaries, jet routes, and fixes for the chosen and adjacent sectors. ZDC personnel and air traffic control (ATC) subject matter experts assisted in developing and validating the scenarios, and in ensuring that the traffic levels represented realistic conditions. A total of eight runs using the four distinct traffic scenarios were developed, tested, and used for this third DRVSM simulation. The four traffic scenarios (referred to as traffic samples 1a, 2a, 3a, and 4a) were each used to create an additional scenario (referred to as 1b, 2b, 3b, and 4b, respectively). Although based on the same raw traffic sample, the “b” samples differed from their “a” counterparts in several ways. First, aircraft identities were changed in the “b” traffic samples to give a different appearance to each scenario. Second, the aircraft designated as non-RVSM-approved differed between the “a” and “b” samples. Additionally, unique events were designed into each of the eight traffic samples in order to allow specific procedures to be exercised and assessed.

2.4 Scenario Conditions

Table 2-1 provides a definition of the eight different runs performed during the simulation, including the traffic sample from which each run was developed, the objective (or objectives) the run addresses, and scripted events included in each run.

2.5 Participants

Six certified professional controllers (CPC) from ZDC who work the simulated sectors (and who were not involved in the definition and validation of the scenarios) staffed the radar (R) and radar associate (RA) positions during the simulation runs. The participating controllers interacted with individuals functioning as pilots (simulation pilots) and ghost controllers. The simulation pilots manipulated computer-generated targets in response to controller instructions. Ghost controllers performed the automation entries and voice communications associated with the airspace surrounding the simulated sectors. ZDC controllers who participated in the scenario development and validation served as expert observers during the simulation to record the participants’ responses to the scripted events, as well as any procedural or operational questions or concerns that arose during the runs.

TABLE 2-1. Description of Scenario Runs Derived from SAR Data

SCENARIO	TRAFFIC SAMPLE	MAPS TO OBJECTIVES	EVENT	SECTOR
1a	1	1, 2	Military non-approved aircraft at RVSM altitude	ALL
			Aircraft unable to maintain RVSM due to equipment failure	16
			Non-approved aircraft requesting climb above FL430	38
			Non-approved aircraft requesting descent below FL290	12
			Aircraft experiencing wake turbulence requests offset	12
1b	1	1, 2	Military non-approved aircraft at FL350	ALL
			Non-approved aircraft requesting descent below FL290	38
			Non-approved aircraft at base/ceiling altitude	38
			Aircraft unable to maintain RVSM due to equipment failure	12
			Non-approved aircraft at base/ceiling altitude	12
			Non-approved ferry flight to be accommodated at RVSM altitude	12
			Non-approved aircraft requesting climb above FL430	16
2a	2	3	60% aircraft are RVSM-approved	ALL
2b	2	3	70% aircraft are RVSM-approved	ALL
3a	3	1, 2	Aircraft unable to maintain RVSM due to equipment failure	38
			Aircraft experiencing wake turbulence requests offset	38
			Aircraft experiencing wake turbulence requests offset	16
			Non-approved aircraft at base/ceiling altitude	16
			Non-approved lifeguard flight to be accommodated at RVSM altitude	12

TABLE 2-1. Description of Scenario Runs Derived from SAR Data (Cont'd)

SCENARIO	TRAFFIC SAMPLE	MAPS TO OBJECTIVES	EVENT	SECTOR
3b	3	1, 2	Aircraft experiencing wake turbulence requests offset or descent	38
			Aircraft unable to maintain RVSM due to equipment failure	38
			Aircraft experiencing wake turbulence requests offset	16
			Non-approved ferry flight to be accommodated at RVSM altitude	16
			Non-approved ferry flight to be accommodated at RVSM altitude	12
			Non-approved aircraft requesting climb above FL430	12
4a	4		Aircraft unable to maintain RVSM due to equipment failure	12
			Non-approved lifeguard flight to be accommodated at RVSM altitude	38
4b	4		Aircraft experiencing wake turbulence requests offset	12
			Aircraft unable to maintain RVSM due to equipment failure	16
			Non-approved aircraft at base/ceiling altitude	16
			Non-approved lifeguard flight to be accommodated at RVSM altitude	38

2.6 Measures

Table 2-2 depicts the subjective and objective data that were collected during the simulation.

TABLE 2-2. Measures Per Objective

Objectives	Data to Be Collected	Source of Data	Measures
1. Assess DRVSM procedures	• Operational input on draft procedures • Procedural issues or questions not covered in draft procedures • Ideas for possible solutions	• Controller comments • Questionnaires	• Not applicable
2. Gain insight for the development of DRVSM training plans	• Training ratings prior to first DRVSM runs to capture perceptions • Ratings to assess number of DYSIM problems needed for workforce training • Suggested improvements for training	• Controller comments • Questionnaires	• Change in ratings as number of DRVSM runs and controllers' experience increases
3. Assess the impacts of using the new altitudes tactically in a conventional vertical separation (CVS) environment	• Operational input on benefit and risks of tactical use • Ratings of impact of tactical use	• Controller comments • Questionnaires	• Workload ratings • Complexity ratings • Potential for error ratings

2.7 Simulation Environment

The simulation was performed in the DSF at the WJHTC. The display system replacement (DSR), the host computer system (HCS), the voice switching and control system (VSCS), and the user request evaluation tool (URET) were, with few differences, configured identically to ZDC's systems. Flight progress strips were not used, since ZDC primarily employs the electronic flight data provided by URET. The target generation facility (TGF) provided high fidelity target generation and movement.

The DSR/Host/URET environment in the DSF was identical to ZDC's for the two tactical use runs, since this reflects the tentative plan for tactical use, should tactical use be implemented. For the six DRVSM runs, however, three modifications were made so that the systems behave in the manner desired for the DRVSM implementation. These changes are:

1. A symbol in the data block was used during the DRVSM scenario runs to indicate that an aircraft was not RVSM-approved. Since it is expected that significantly more aircraft will be approved than not, coding the non-RVSM-approved aircraft reduces clutter on the controller's situation display. The indicator was a coral box around the fourth character in

the second line of the data block for non-RVSM-approved aircraft. The Air Traffic DSR Evolution Team (ATDET), the team responsible for the final computer human interface (CHI) design for DRVSM, provided this design for the indicator.

2. The conflict alert (CA) logic used by the HCS was updated to accurately reflect the revised vertical separation standards for DRVSM.

3. Because the conflict probe logic used by URET had not yet been updated, the conflict probe and trial planning feature had to be deactivated for the purposes of this simulation to avoid giving erroneous alerts for pairs of RVSM-approved aircraft with at least 1000-foot vertical separation.

2.8 Data Collection

With the exception of data on separation violations[1], only subjective data were collected. The subjective data collected include responses to questionnaires (completed by the six ZDC participants) and controller comments during the debrief sessions (from the six ZDC participants and the ZDC expert observers). Table 2-3 details each type of questionnaire used during this simulation, the frequency with which each was used, and their distinct purposes.

TABLE 2-3. Summary of Questionnaires

Method	Users	Frequency	Completed	Purpose
Background Questionnaire	Participants	Once	After orientation briefing	Gather controller demographic information.
Tactical Use Questionnaire	Participants	Once	After the completion of the second tactical use run	Provide controller feedback on the operational impacts and benefits of tactical use.
Pre-RVSM Run Questionnaire	Participants	Once	After RVSM classroom training and prior to the first RVSM run	Collect controller perceptions of RVSM prior to hands-on experience, so that perceptions can be compared to actual experiences after RVSM runs.
Post-Run Questionnaire	Participants	Every run	After each run	Elicit controller comments related to procedures and training implications.

[1] No separation violations occurred during the third DRVSM simulation.

3. RESULTS FOR OBJECTIVE 1: ASSESS DRVSM PROCEDURES

A primary goal for the third DRVSM simulation was to assess the air traffic procedures needed for DRVSM. Accordingly, preliminary procedures and corresponding phraseology were drafted for use during the six DRVSM runs. Participants were provided with a procedures familiarization briefing prior to the first DRVSM run.

The preliminary DRVSM procedures used during the simulation are presented in Section 3.1, while the assessment results are in Section 3.2. The phraseology drafted for use during this simulation is included in Appendix A.

3.1 Preliminary DRVSM Procedures

The preliminary procedures assessed during the simulation were based on the prior efforts of the DRVSM Procedures Workgroup. This group identified five primary procedural topics and provided suggestions for each topic. The five procedural topic areas are:

1. Accommodation of non-RVSM-approved military, lifeguard, or ferry flight aircraft.
2. Non-RVSM-approved aircraft transitioning through RVSM airspace.
3. Base/ceiling coordination with abutting sectors.
4. Aircraft loss of equipment required for RVSM operation.
5. Wake turbulence in RVSM airspace.

To ensure that each participant was able to exercise each of the procedures, special events were scripted into each run to create the opportunity to use one or more of the procedures. (See Table 2-1.) The simulation design was specifically created to ensure that over the course of the six DRVSM runs, each participant would have the opportunity to exercise all of the procedures at least once while staffing the R-side position, and at least once while staffing the RA-side position.

3.1.1 Accommodation of Non-RVSM Approved Military or Lifeguard Aircraft

Draft Procedure: Non-RVSM approved military, lifeguard, and ferry flights are to be accommodated within RVSM airspace, traffic permitting[2]. Vertical separation of 2000 feet shall be applied to such aircraft.

3.1.2 Non-RVSM Approved Aircraft Transitioning Through RVSM Airspace

Draft Procedure: Non-RVSM approved aircraft, other than military, lifeguard, or other excepted aircraft, should be permitted to transition to altitudes above or below RVSM airspace, traffic permitting[2]. Aircraft shall only be leveled off in climb or descent for separation purposes, not for the purpose of burning off fuel to accommodate the user. Prior to climbing into RVSM airspace, aircraft shall be coordinated one sector ahead to insure system acceptance for transition. Vertical separation of 2000 feet shall be applied to such aircraft.

For the purposes of this simulation, participants were instructed to coordinate non-RVSM-approved aircraft with the next sector. For a non-RVSM-approved aircraft already in RVSM

[2] The traffic scenarios were specifically designed to permit accommodation of the non-RVSM-approved aircraft, so that the accommodation and transition procedures could be exercised and assessed.

airspace, coordination was to occur prior to handoff. For a non-RVSM-approved aircraft requesting clearance, but not yet cleared into RVSM airspace, coordination with the next sector was to occur prior to the initial clearance into RVSM airspace. The participants were also instructed to inform the supervisor of the presence of a non-RVSM-approved aircraft in their airspace. It is expected that supervisors will perform forward coordination with adjacent affected areas or facilities and will coordinate with traffic flow management personnel, as needed, when a non-approved aircraft is in RVSM airspace.

3.1.3 Base/Ceiling Coordination Requirements with Abutting Sectors

Draft Procedure: A non-RVSM approved aircraft operating at a sector's base or ceiling altitude requires coordination with the sector that owns the airspace immediately above or below so as to insure 2000 feet separation is maintained from any aircraft operating in the adjacent airspace.

For a non-RVSM approved aircraft flying at the base or ceiling altitude of the next sector, participants were instructed to perform a point out and verbally coordinate with the affected sector. Depending on stratifications or shelves, this could require coordination with more than one sector.

3.1.4 Aircraft Loss of Equipment Required for RVSM Operation

Draft Procedure: An aircraft operating within RVSM airspace that loses an equipment component required for RVSM flight and advises ATC "unable RVSM due to equipment" shall be removed from RVSM airspace. Equipment suffix shall be amended to reflect the revised status of aircraft equipage.

3.1.5 Aircraft Experiencing Wake Turbulence in RVSM Airspace

Draft Procedure: Aircraft experiencing wake turbulence in RVSM airspace shall advise ATC of occurrence and pilot request. Controller should approve pilot request, traffic permitting.

3.2 Procedures Assessment

Participants were asked to provide both written and verbal feedback on the draft procedures. The questionnaire the controllers completed after each DRVSM run requested feedback on the use and effectiveness of the preliminary procedures, the adequacy of the training provided on the procedures, and any additional procedural issues not covered in the draft procedures. Procedural topics were then discussed during the debrief session following each run.

Overall, participants felt the draft procedures were appropriate and that the training they received was adequate. Each of the team's suggested improvements and additions to the draft procedures, detailed in the following sections, related to the presence of non-RVSM-approved aircraft in RVSM airspace.

3.2.1 Pilot Phraseology for Non-RVSM-Approved Aircraft

Controller awareness of the presence of a non-RVSM-approved aircraft in RVSM airspace is critical to maintaining the safe operation of the NAS under DRVSM. Accordingly, the data block for a non-approved aircraft in RVSM airspace is color coded to allow the controller to discriminate aircraft that require 2000-foot vertical separation. The verbal coordination procedures between controllers are designed to reinforce controller awareness of non-RVSM-approved aircraft entering their sector. As an added measure, the team suggested that pilots of non-RVSM-approved aircraft identify themselves as such on initial radio contact with each sector traversed while in RVSM airspace. During subsequent DRVSM runs, this procedure was followed and the participants agreed this additional level of redundancy is appropriate, given the safety-critical nature of the information.

3.2.2 Supervisory Notification of Non-RVSM-Approved Aircraft

The participants suggested that the procedure for informing the operations supervisor when a non-RVSM-approved aircraft is operating in RVSM airspace be streamlined. Three distinct cases were discussed: (1) a non-RVSM-approved aircraft to be accommodated at level flight at a RVSM altitude, (2) a non-RVSM-approved aircraft requesting to transition through RVSM airspace, and (3) a RVSM-approved aircraft that experiences an equipment loss that changes its RVSM approval status.

Non-RVSM-approved military, lifeguard, or ferry flights desiring to be accommodated at an RVSM altitude (e.g., requesting a final altitude of FL320) will be expected to pre-coordinate their request in advance with the appropriate traffic flow management personnel (the System Command Center and/or the Traffic Management Unit in the affected center). In this case, traffic flow personnel should coordinate the approval of such a request with the operations supervisors of the affected areas of specialization. The supervisor would then be expected to alert the affected sectors, and to adjust sector staffing, if necessary, to accommodate the additional workload represented by the presence of a non-RVSM-approved aircraft in RVSM airspace. The operations supervisor of the first area traversed by the non-approved aircraft would also forward coordinate with the supervisor of the next area. Thus, the participants suggested that the only situation that requires a controller to notify the supervisor is when a non-RVSM-approved flight in RVSM airspace is inbound from another facility.

In the case of a non-RVSM-approved aircraft requesting a clearance to transition through RVSM airspace, the controller should gain approval from the next sector prior to granting a clearance into RVSM airspace, and then notify the supervisor. Similarly, the controller should notify the supervisor in the event that an RVSM-approved aircraft loses equipment required for RVSM operation.

The participants’ suggested revision to the procedure is for the controller to notify the supervisor only in the following cases:

1. A non-RVSM-approved aircraft is inbound from another facility.
2. A non-RVSM-approved aircraft has started to climb or descend into RVSM airspace.
3. An approved aircraft loses equipment required for RVSM operation.

3.2.3 Inter-Sector Coordination of Non-RVSM-Approved Aircraft

The participants suggested that the importance of sector-to-sector coordination of an approval request (APREQ) for a non-RVSM-approved aircraft needs to be stressed during classroom training, particularly since DYSIM does not support interaction between adjacent sectors.

3.2.4 Aircraft Loss of Equipment Required for RVSM Operation

The participants found that sometimes the best solution to achieve 2000-foot vertical separation for an aircraft that has lost its RVSM capability was to climb the aircraft until traffic cleared, allowing the aircraft to subsequently be cleared from RVSM airspace. They suggested clarifying during training that this is an acceptable solution to dealing with such aircraft situations.

4. RESULTS FOR OBJECTIVE 2: GAIN INSIGHT FOR THE DEVELOPMENT OF DRVSM TRAINING PLANS

A significant focus of near-term DRVSM program efforts will be the establishment of the DRVSM training plan for the en route controller workforce. The third DRVSM simulation was designed to obtain as much field input as possible on training needs. Three types of subjective data were collected for training: verbal controller feedback from the debrief sessions that followed each DRVSM simulation run, written controller comments, and participants' numerical ratings collected via questionnaire responses. Insights were gained on training approaches, areas to emphasize in controller training, areas to emphasize in supervisory training, specific skills necessary for DRVSM, and the duration of DRVSM simulation training.

4.1 Verbal Feedback on DRVSM Training Approach

The participants' inputs on training approaches for DRVSM include:

- Like recent CPC training programs for DSR and URET, DRVSM training should encompass computer-based-instruction (CBI), classroom training, and simulation training. While these recent training programs focused on the ability to interact with new systems and practice integrating them into the sector operations, DRVSM training is quite different since it needs to focus on separation, scanning for non-approved aircraft, applying different separation standards for approved and non-approved aircraft, the impact of changes in national and local procedures and letters of agreement (LOA), and the impact of non-approved aircraft on upstream sectors.
- Given the necessary focus on separation, the participants felt that the DRVSM training program needs to be more consistent across areas of specialization and across centers than recent CPC training programs.
- Training simulation problems of 20 to 30 minutes duration would be more effective for DRVSM than the usual 45 to 60 minute DYSIM problems.
- Each training problem should be very focused on a small set of specific training goals.
- Revisions to local standard operating procedures (SOP) and LOAs will be needed to be complete prior to the start of training so they can be integrated into local training.
- An early CBI or some other form of early familiarization for the workforce on DRVSM may be very beneficial. The goal would be to get the workforce thinking and talking about the changes inherent in DRVSM.
- The fact that DYSIM currently does not support dynamic interactions between adjacent simulated sectors is a significant limitation for DRVSM training, particularly given the impact of non-RVSM-approved aircraft on upstream sectors and the need for an APREQ.

4.2 Verbal Feedback and Written Comments for Controller Training Emphasis

Although controllers consistently responded (via written questionnaires) that they saw nothing missing or that needed improvement in the DRVSM training materials briefed prior to their first DRVSM run, the group discussions during the debrief sessions were highly effective in identifying topics that either need to be added to the classroom training, or that were covered but misunderstood by one or more of the participants. Areas to be reinforced during DRVSM training include:

- The importance of sector-to-sector coordination to APREQ a non-approved aircraft. In particular, situations in which the controller needs to APREQ the non-approved aircraft with multiple sectors should be highlighted and clearly demonstrated (e.g., when a non-approved aircraft is at an altitude that happens to be at the base or ceiling altitude of the next sector).
- APREQ requirements apply to ***all*** non-RVSM-approved aircraft. Some controllers mistakenly thought APREQ requirements applied only to non-approved aircraft transitioning through RVSM airspace to get above FL410 or below FL290, and not to military, lifeguard, or ferry flights that had been pre-coordinated for accommodation, traffic permitting, at a level RVSM altitude.
- The upper and lower bounds of RVSM airspace. Specifically, clearly demonstrate the following cases:
    - FL420 is not a valid final altitude for any aircraft, regardless of its RVSM status.
    - If there is a non-RVSM-approved aircraft at FL280, FL290 is an available altitude for a RVSM-approved aircraft. If, however, the non-approved aircraft is at FL290, FL300 is not available.
- DRVSM remains exclusionary airspace during slow traffic periods when workload could otherwise permit accommodation. An aircraft that is non-RVSM-approved, is not one of the types of flights to be accommodated with prior approval (e.g., military, lifeguard, or ferry flights), and is not capable of flying at FL430 is precluded from FL290 – FL410. A bad ride, for example, does not justify giving a non-RVSM-approved aircraft an RVSM altitude. The only valid exception is a declared emergency.
- The rules for when the non-RVSM-approved indicator is displayed or not displayed below FL290 are complex and need to be clearly illustrated during training. For example, when does the controller need to actively look for the non-approval status ***before*** giving a clearance to climb?
- Procedures for aircraft that lose their ability to maintain RVSM. Clearly demonstrate that such situations are not emergencies, per se. The goal is to achieve 2000-foot vertical separation as quickly as possible, even if this means climbing the aircraft temporarily to a higher RVSM altitude). Once traffic permits, remove the aircraft from RVSM airspace. Removal from RVSM airspace may mean descending the aircraft to FL280 ***or*** climbing to FL430.
- Initially, controllers should expect to see errors in the equipage suffix filed in flight plans. Some pilots may initially forget to file a “/W” or “/Q” suffix (which indicates the aircraft is RVSM-approved), and, therefore, the aircraft may erroneously be designated as non-approved. If the controller verifies the aircraft is RVSM-approved, the equipage suffix needs to be corrected in Host.

4.3 Verbal Feedback for Supervisory Training Emphasis

Some of the training feedback provided may be best incorporated into supervisory personnel training. This includes:

- The presence of a non-RVSM-approved aircraft increases workload and complexity, and may require the addition of an RA-side at a sector that would not otherwise need one. For this reason, supervisory awareness of the presence of a non-approved aircraft in RVSM airspace is critical. Training should emphasize coordination and notification procedures for non-RVSM-approved aircraft.
- The fact that DRVSM airspace is exclusionary may impact traffic density and flows at some sectors by causing aircraft that would otherwise fly at higher altitudes into airspace below FL290. Special care should be used, especially during the early stages of DRVSM until the changes in traffic flows becomes routine.
- Some participants felt there is the potential with DRVSM to reduce the buffer between "very busy, but okay" and "down the tubes". Today, one indication that the sector team is reaching workload saturation is when all the altitudes are in use. Since there are six more altitudes with DRVSM, a sector may reach saturation before all the altitudes are used. Consequently, the controller may not fully realize how busy he/she is becoming. Supervisory training should stress the need for vigilance on monitoring sector workload and staffing.

4.4 Controller Perceptions of DRVSM Skills

To gain additional insights into training needs, ten distinct skills or operational changes associated with DRVSM operations were identified. They are:

(1) Issuing altitude clearances to the newly added RVSM altitudes, e.g., "USA123 climb and maintain FL320".
(2) Monitoring and applying the revised appropriate altitudes for direction of flight.
(3) Using a RVSM altitude to resolve a confliction (e.g., instead of vectoring).
(4) Monitoring separation and identifying/resolving conflictions, given the changed separation criteria.
(5) Scanning the situation display to identify non-RVSM-approved aircraft.
(6) Maintaining separation for non-RVSM-approved aircraft in RVSM airspace.
(7) New requirements for coordination and pointouts.
(8) Procedural changes.
(9) Phraseology changes.
(10) Changes to sector stratifications.

Controllers were asked to rate on a scale of 1 to 3, each of these ten skills/changes against two distinct criteria described in Table 4-1. Each participant rated the training relevance and ease of training of each of the ten skills/changes prior to their first DRVSM run to document their initial perceptions, and then after each of the six DRVSM runs to capture the changes in their views as they gained DRVSM experience.

TABLE 4-1. DRVSM Skills/Changes Criteria and Rating Scales

	Criteria	Rating Scale
Training Relevance	Degree of relevance of the skill or change to adapting to (i.e., becoming comfortable with) RVSM operations	1 – Not at all relevant 2 – Somewhat relevant 3 – Very relevant
Ease of Training	Ease of training the skill or change as measured by the amount of simulation training required to achieve proficiency in the skill	1- Minimal simulation training required for proficiency (e.g., 1 hour) 2- Moderate simulation training required for proficiency (e.g., 3-4 hours) 3- Significant simulation training required for proficiency (e.g., more than 6 hours)

An understanding of which new skills or changes are most important to a controller's ability to adapt to DRVSM operations and the amount of simulation time needed to develop each skill will help in structuring the DRVSM training. An analysis of the training relevance ratings per DRVSM run indicates that the ratings tended to stabilize after the first three DRVSM runs. Further, the ratings in the earlier runs sometimes differed substantively from those in the later runs, after the participants had the benefit of a few hours of DRVSM experience. For this reason, the average ratings for the last three runs are considered good indicators for the actual relevance or importance of each skill to adapting to DRVSM. Table 4-2 provides the training relevance ratings for the ten skills/changes in decreasing order of importance, as well as a comparison with the controllers initial perception of how relevant the skill /change would be. A similar analysis was performed for the ease of training ratings. These results are shown in Table 4-3.

TABLE 4-2. DRVSM Skills/Changes Training Relevance Ratings

Skill/Factor	Avg. Rating for DRVSM Runs 4, 5 and 6	Experience vs. Initial Perception (Less, Same, or More)	Average Rating Prior to First DRVSM Run (Perception)
Maintaining separation for non-RVSM-approved aircraft in RVSM airspace	2.5	Less	2.8
Using a RVSM altitude to resolve a confliction (e.g., instead of vectoring)	2.5	More	1.8
Scanning the situation display to identify non-RVSM-approved aircraft	2.2	Less	2.8
Monitoring separation and identifying/resolving conflictions, given the changed separation criteria	2.1	Less	2.3
Procedural changes	2	Less	2.3
Changes to sector stratifications	1.9	Less	2.3
Monitoring and applying the revised appropriate altitudes for direction of flight	1.9	Less	2.2
Issuing altitude clearances to the newly added RVSM altitudes, e.g., "USA123 climb and maintain FL320"	1.8	More	1.7
New requirements for coordination and pointouts	1.7	Less	2.2
Phraseology Changes	1.4	Less	1.7

TABLE 4-3. DRVSM Skills/Changes Ease of Training Ratings

Skill/Factor	Avg. Rating for DRVSM Runs 4, 5 and 6	Experience vs. Initial Perception (Easier, Same, or Harder)	Average Rating Prior to First DRVSM Run (Perception)
Maintaining separation for non-RVSM-approved aircraft in RVSM airspace	2.2	Easier	2.3
Scanning the situation display to identify non-RVSM-approved aircraft	2	Same	2
Monitoring separation and identifying/resolving conflictions, given the changed separation criteria	1.8	Easier	2
Monitoring and applying the revised appropriate altitudes for direction of flight	1.7	Harder	1.3
Using a RVSM altitude to resolve a confliction (e.g., instead of vectoring)	1.6	Harder	1.5
Procedural changes	1.6	Easier	1.8
Changes to sector stratifications	1.6	Harder	1.3
Issuing altitude clearances to the newly added RVSM altitudes, e.g., “USA123 climb and maintain FL320”	1.6	Harder	1.3
New requirements for coordination and pointouts	1.4	Easier	1.7
Phraseology Changes	1.2	Same	1.2

Not surprisingly, the rank ordering of the skills under both rating criteria are fairly similar, with skills associated with identifying and separating non-RVSM-approved aircraft in RVSM airspace topping both lists, and phraseology, coordination, and pointout changes at the bottom. This information will be used in structuring specific goals for training simulation problems.

4.5 Analysis of Training Duration Ratings

The questionnaires for the third DRVSM simulation were also designed to obtain insight into the appropriate duration of DRVSM training, particularly simulation training. Prior to the first DRVSM run, participants were asked the following question: Which of the following statements **best** describes your view of RVSM training at this time?

1	I feel well prepared to begin live RVSM operations now.
2	RVSM training should include approximately 1 hour of classroom training, and 3 - 4 simulation (DYSIM) problems, approximately 8 hours of training total.
3	RVSM is a significant change to ATC operations and preparing the workforce will require significantly more than 8 hours of training.

To assess how their views changed as they gained experience with DRVSM, the participants were asked the following question after each of the six DRVSM simulations: Which of the following statement **best** describes your view of RVSM training at this time?

1	I feel well prepared to begin live RVSM operations now.
2	Although I feel prepared to begin live RVSM operations now, additional simulation practice or experience would be beneficial.
3	I feel additional simulation experience is needed prior to the start of live RVSM operations.

Table 4-4 provides the results of the ratings, averaged over the six participants. An average rating of 2.2 prior to the first DRVSM run indicates that the participants tended to feel that more than eight hours of training would be required for DRVSM. As they became more experienced, however, their estimate of the amount of training required tended to decrease.

TABLE 4-4. Training Duration Ratings

	Prior to First DRVSM Run	After 1 DRVSM Run	After 2 DRVSM Runs	After 3 DRVSM Runs	After 4 DRVSM Runs	After 5 DRVSM Runs	After 6 DRVSM Runs
Cumulative Training[3]	1 Hour	2 Hours	3 Hours	4 Hours	5 Hours	6 Hours	7 Hours
Avg. Rating	2.2	2.2	2.2	1.8	1.5	1.7	1.5

In addition to the average rating, it is pertinent to look at how many of the participants felt well prepared to begin live DRVSM operations after each run, and how many felt they needed more simulation time prior to starting live operations.

[3] Cumulative training includes classroom and simulation training. Classroom training was provided prior to the first DRVSM run and lasted approximately one hour. Each DRVSM simulation run was essentially an hour.

TABLE 4-5. Distribution of Training Duration Ratings

	Prior to First DRVSM Run	After 1 DRVSM Run	After 2 DRVSM Runs	After 3 DRVSM Runs	After 4 DRVSM Runs	After 5 DRVSM Runs	After 6 DRVSM Runs
Number of “1” responses (i.e., well prepared to start live DRVSM ops)	2	2	3	4	4	3	4
Number of “3” responses (i.e., need additional simulation before live DRVSM ops)	3	3	2	1	1	1	1

At least for this small sample, the data provided in Tables 4-4 and 4-5 suggest that 3 to 4 hours of simulation time produced approximately the same degree of comfort with DRVSM operations as 6 hours of simulation time.

5. RESULTS FOR OBJECTIVE 3: ASSESS THE IMPACTS OF USING RVSM ALTITUDES TACTICALLY IN CVS ENVIRONMENT

The FAA is considering whether to implement “tactical” use of RVSM altitudes prior to full DRVSM implementation in January 2005. Under tactical use, controllers would have the opportunity to use RVSM standards between two RVSM-approved aircraft in their own sector. Prior to handoff to the next sector, the controller would return the aircraft to conventional separation or coordinate otherwise. If adopted, tactical use would be optional, providing a tool available for use at the sector team’s discretion.

From experience in other locales, it is known that tactical use is effective only if the percentage of RVSM-approved aircraft is large, e.g., 60 percent or higher. Consequently, the earliest likely date for instituting tactical use is June 2004, six months prior to the full implementation of DRVSM. The FAA is investigating the viability, cost, and benefits of instituting tactical use for this relatively short period of time.

To obtain field controller input on the operational benefits, the first two runs of the third DRVSM simulation were designed to assess tactical use of RVSM altitudes in a CVS environment. The percentage of RVSM-approved aircraft varied between 60 and 70 percent in the two tactical runs. Prior to the first run, the participants were given an introductory familiarization briefing on tactical use.

5.1 Overview of Tactical Use Results

All of the participants indicated they found tactical use to be beneficial to the sector team (and five out of six participants felt the benefit should be significant), ***provided*** there is a means of distinguishing RVSM-approved aircraft from non-approved aircraft on the radar scope. Key benefits cited included a reduction of vectoring (e.g., a 1000-foot altitude change for one aircraft can eliminate the need to vector several aircraft), less potential for operational errors, and facilitating the transition to full DRVSM operations.

Having an indicator for non-RVSM-approved aircraft on the radar scope was considered essential for tactical use by all of the participants, yet this capability is not planned to be available until full DRVSM implementation. During the tactical use simulation runs, the only means of discerning whether an aircraft was RVSM-approved was searching for the aircraft's equipage suffix on the URET aircraft list. Since the sectors were staffed with two controllers during the tactical runs, the RA-side was able to perform the required monitoring and searching of the equipage field to identify opportunities for the R-side to use 1000-foot separation. The participants felt that in a one-person sector, or a busy two-person sector, the lack of an indication of RVSM status in the data block would effectively eliminate their ability to take advantage of tactical use.

The other automation concern associated with tactical use is the fact that conflict alert is triggered each time a controller uses RVSM separation. This was considered distracting by all the participants and very distracting by some. The fact that conflict alert will sometimes be displayed at adjacent sectors, not just the sector applying RVSM separation, could be particularly problematic given that controllers who chose not to use RVSM tactically will, nonetheless, be affected. Moreover, since use would be optional during the tactical phase, changing conflict alert parameters for RVSM-approved aircraft pairs is not viable.

5.2 Use of RVSM Altitudes Tactically

Controllers were asked to rate the extent to which there would be opportunities to use RVSM altitudes tactically when considering the full range of operations found in their areas of specialization. On a scale of 1 to 5, with 1 meaning "none", 3 "moderate" and 5 "significant", the average rating was 3.7. Individual responses were spread across the full range of ratings. For example, while one controller indicated he/she foresees no situations in which tactical use of RVSM altitudes would be the best solution, others felt there would be significant opportunity to use it. When asked separately to rate the opportunities to use RVSM altitudes tactically during the simulation runs, the results were identical.

While the participants in the simulation represent a very small sample size, it is likely that some proportion of the controller population will choose to **not** use RVSM altitudes tactically. Since the participants found that the tactical use runs served as effective training for the subsequent DRVSM runs, the fact that the use of RVSM altitudes tactically would be optional could actually complicate the training program for full DRVSM implementation.

5.3 Impact of Tactical Use

The participants were asked to rate the impact of tactical use on workload, sector complexity, and potential for error on a scale of 1 to 5, with 1 indicating a "significant reduction", 3 "no impact", and 5 "significant increase". The average ratings for both tactical use runs are shown in Table 5-1.

TABLE 5-1. Impact of Tactical Use

	Workload	**Sector Complexity**	**Potential for Error**
Average Rating	3 (See below)	2.5	2.3

Analysis of the individual participants' ratings and written comments indicate that there was a general consensus that tactical use did not negatively affect sector complexity or the potential for error during the two tactical use runs. This finding is consistent with the average ratings of 2.5 and 2.3 for sector complexity and potential for error, respectively. Some participants felt there was no impact, while others felt there was either a moderate or significant reduction in sector complexity and potential for error due to tactical use.

While the average rating for impact on workload was 3, this statistic is misleading, since every participant felt tactical use had *some* impact, and there was significant disagreement as to the nature of the impact. Three participants felt sector workload was reduced, (one indicated a significant reduction, and two a slight reduction), and the remaining three felt it was increased, with one feeling it was significantly increased. For those indicating workload increased, the comments indicated the increase was due to the efforts required to ascertain aircraft eligibility for 1000-foot separation and to assess whether conflict alert warnings represented a real confliction or a valid tactical use of RVSM altitudes.

5.4 Benefits and Risks for Tactical Use

Participants' input on the benefits and risks of implementing tactical use was collected via written questionnaires and group debrief sessions. The following benefits were identified:

- Reduction of vectoring (e.g., a 1000-foot altitude change for one aircraft can eliminate the need to vector several aircraft). This would be particularly helpful in narrow sectors with little room to vector.
- Less potential for operational errors. Not only does tactical use provide another option to resolve a potential confliction, altitude separation can be achieved more quickly when only 1000 feet is required.
- In sectors in which there are major streams of crossing traffic and altitude congestion under CVS, controllers may be able to solve a complex situation by moving a single aircraft.
- Experience in using RVSM altitudes tactically probably reduces the amount of training needed to transition to full DRVSM (but only for those controllers who opt to use RVSM altitudes tactically).

The risks associated with tactical use include those resulting from the automation issues identified in Section 5.1, the general risk associated with any significant operational change, and the implications of optional use. Some controllers were concerned that the workforce could be lulled into a false sense of security given that controllers at the next sector may not accept a handoff for aircraft separated using tactical RVSM. Others felt this risk is one that they deal with every day, since there are many reasons a handoff request may be denied.

5.5 Overall Utility of Implementing Tactical Use

Participants were asked to rate the overall utility of implementing tactical use by considering factors such as benefits, impacts, costs, and the fact that it would be in effect for no more than six months prior to full DRVSM implementation. Costs were not quantified, but described only as broad categories of effort (such as workforce training for tactical use, then retraining for full DRVSM deployment, and procedures development). The following 5-point rating scale was used:

1	Not at all useful in my area of specialization
3	No impact (positive or negative) to my area of specialization
5	Extremely useful in my area of specialization

The average rating was 4. Four of the six participants felt it would be useful (a rating of 4) or extremely useful (a rating of 5), and two were neutral (a rating of 3).

6. CONCLUSIONS

The findings of the third DRVSM simulation serve to validate and enhance the draft DRVSM procedures, support the development of an effective DRVSM training plan, and provide the FAA with information to support a decision on tactical use of RVSM altitudes prior to full DRVSM deployment.

With two exceptions, the preliminary procedures developed for the simulation were determined to be complete and effective. The participants suggested the procedure for controllers to notify supervisory personnel of the presence of a non-RVSM-approved aircraft be streamlined to take advantage of the fact that military, lifeguard, and ferry flights requesting to fly at a RVSM altitude will be coordinated with traffic flow management in advance. With pre-coordination between traffic flow and supervisory personnel, controllers should learn of non-RVSM-approved aircraft to be accommodated at a RVSM altitude in their sector from their operations supervisor rather than the reverse. Secondly, participants suggested an additional procedure to help ensure continual situational awareness of a non-RVSM-approved aircraft operating in RVSM airspace. Specifically, a requirement will be added for pilots of non-RVSM-approved aircraft to state their flight is non-RVSM-approved on initial radio contact at each sector traversed while operating in RVSM airspace. These changes are being incorporated into the proposed DRVSM revisions to FAA Handbook 7110.65 and FAA Order 7210.3.

Several findings of the third DRVSM simulation will be incorporated into the DRVSM training plan for en route controllers and supervisors. Meaningful data was obtained to answer the single largest unknown for the training plan, namely the duration of simulation training needed to adapt to DRVSM operations. From the subjective data collected, it appears that a total simulation time of three to four hours per controller will suffice. Based on suggestions from the field participants, the training plan will consider using six to eight simulation problems of 20 to 30 minutes in duration each, instead of 45 to 60 minute problems, and that each problem will have specific, well-defined training objectives. Based on the simulation findings, the individual skills most relevant to adapting to DRVSM operations are better understood, as is the amount of simulation training required to acquire each skill. Moreover, input gained will assist in developing more effective classroom training and CBI materials.

Lastly, the issues and risks of implementing tactical use of RVSM altitudes prior to the full implementation of DRVSM in January 2005 are now better understood. A key finding of the simulation is that the plan to display the non-RVSM indicator in data blocks only for full DRVSM operations, and not for tactical use, is not viable. Lack of a visual indication in the data block would effectively preclude the ability of the sector to apply reduced vertical separation tactically during single-person sector operations or during heavy traffic periods. The participants found the manual search and analysis of flight data to identify RVSM-approved aircraft sufficiently workload intensive that it would be feasible only in two-person sector operations and only then with moderate traffic densities. This effectively eliminates many of the benefits of tactical use. The participants also found it distracting to receive conflict alert notifications each time tactical use was applied between two RVSM-approved aircraft, particularly at a sector adjacent to the sector applying tactical use. While the first issue may be able to be resolved if it is feasible to display the non-RVSM-approval indicator during the tactical use timeframe, there is no viable solution for the second issue. Conflict alert parameters cannot be modified to RVSM standards during the tactical use timeframe since use of RVSM altitudes tactically is optional. Finally, the optional nature of tactical use would significantly complicate the training program for full DRVSM implementation by effectively necessitating one training program for those who use RVSM tactically on a routine basis (and who would have already developed many of the necessary skills associated with adapting to DRVSM) and those who do not. Given these factors and the additional costs associated with implementing tactical use for a six-month period at best, the negatives associated with tactical use appear to outweigh the positives.

APPENDIX A
DRAFT CONTROLLER AND PILOT PHRASEOLOGY

ACCOMMODATION OF NON-RVSM APPROVED MILITARY OR LIFEGUARD AIRCRAFT

Phraseology: For pilot/controller communication

CIRCUMSTANCE	**PHRASEOLOGY**
ATC wish to know RVSM status of flight	**Confirm RVSM Approved**
Pilot indication that flight is RVSM approved	**Affirm RVSM**
Pilot indication that flight is non-RVSM approved	**Negative RVSM**
Pilot of State aircraft indicating that flight is non-RVSM approved.	**Negative RVSM State Aircraft**
ATC denial of clearance into RVSM airspace	**Unable clearance into RVSM airspace, maintain (or descend to, or climb to) FL**

Phraseology: For coordination between ATC personnel/units

MESSAGE	**PHRASEOLOGY**
To verbally supplement an automated estimate message exchange which does not automatically transfer approval status	**Negative RVSM** or **Negative RVSM State Aircraft** (as applicable)
To verbally supplement estimate messages of non-RVSM approved aircraft	**Negative RVSM or Negative RVSM State Aircraft** (as applicable)

NON-RVSM APPROVED AIRCRAFT TRANSITIONING THROUGH RVSM AIRSPACE

Phraseology: For pilot/controller communication

CIRCUMSTANCE	PHRASEOLOGY
ATC wish to know RVSM status of flight	**Confirm RVSM Approved**
Pilot indication that flight is RVSM approved	**Affirm RVSM**
Pilot indication that flight is non-RVSM approved	**Negative RVSM**
Pilot of State aircraft indicating that flight is non-RVSM approved.	**Negative RVSM State Aircraft**
ATC denial of clearance into RVSM airspace	**Unable clearance into RVSM airspace, maintain (or descend to, or climb to) FL**
Pilot requesting clearance through RVSM airspace and is non-RVSM approved.	**(call sign) request climb to FL ___, negative RVSM**

Phraseology: For coordination between ATC personnel/units

MESSAGE	PHRASEOLOGY
To verbally supplement an automated estimate message exchange which does not automatically transfer approval status	**Negative RVSM** or **Negative RVSM State Aircraft** (as applicable)
To verbally supplement estimate messages of non-RVSM approved aircraft	**Negative RVSM or Negative RVSM State Aircraft** (as applicable)

Base/ceiling coordination requirements with abutting sectors

Phraseology: For coordination between ATC personnel/units

MESSAGE	PHRASEOLOGY
To verbally supplement an automated estimate message exchange which does not automatically transfer approval status	**Negative RVSM** or **Negative RVSM State Aircraft** (as applicable)
To verbally supplement estimate messages of non-RVSM approved aircraft	**Negative RVSM or Negative RVSM State Aircraft** (as applicable)

AIRCRAFT LOSS OF EQUIPMENT REQUIRED FOR RVSM OPERATION

Phraseology: For pilot/controller communications

CIRCUMSTANCE	PHRASEOLOGY
Pilot reporting equipment degraded below RVSM requirements	**Unable RVSM due to Equipment**
ATC requesting pilot to report when able to resume RVSM.	**Report able to resume RVSM**
Pilot ready to resume RVSM after equipment/weather contingency.	**Ready to resume RVSM**

AIRCRAFT EXPERIENCING WAKE TURBULENCE IN RVSM AIRSPACE

Phraseology: Use existing phraseology associated with turbulence instances.