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"Zero/Zero" Rotorcraft Certification Issues

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Volume I
Executive Summary

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Final Report

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15. Supplementary Notes

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16. Abstract

This report analyzes the "Zero/Zero" Rotorcraft Certification Issues from the perspectives of manufacturers, operators, researchers and the FAA. The basic premise behind this analysis is that "zero/zero", or at least extremely low visibility, rotorcraft operations are feasable today from both a technological and an operational standpoint. The questions and issues that need to be resolved are: What certification requirements do we need to ensure safety? Can we develop procedures which capitalize on the performance and maneuvering capabilities unique to rotorcraft? Will extremely low visibility operations be economically feasable?

Volume I of this report provides an overview of the Certification Issues Forum held in Phoenix, Arizona in August of 1987. It presents a consensus of 48 experts from the government, manufacturer, and research communities on 50 specific Certification Issues. The topics of Operational Requirements, Procedures, Airworthiness and Engineering Capabilities are discussed.

Volume II presents the operator perspectives (system needs), applicable technology and "zero/zero" concepts developed in the first 12 months of research of this project.

Volume III provides the issue-by-issue deliberations of the experts involved in the Working Groups assigned to deal with them in the Issues Forum.

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Barry R. Billmann	FAA Technical Center
Richard A. Birnbach	FAA Flight Standards
William J. Cox	Aviation Systems Concepts, Inc.
David L. Green	Starmark Corporation
Jake C. Hart	Aerospatiale Helicopter Corporation
Jim S. Honaker	FAA Southwest Region
Peter V. Hwoschinsky	FAA
Donald P. Pate	FAA Aviation Standards National Field Office
Thomas G. Sandberg	Sikorsky Aircraft
John L. Thompson	Systems Control Technology
Joseph J. Traybar	FAA Technical Center
Richard A. Weiss	FAA
Howard A. Wheeler	RJO Enterprises

Table of Contents

LIST OF TABLES

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1.0 INTRODUCTION

The "Zero/Zero" Rotorcraft Certification Issues Forum was sponsored as part of a joint NASA/FAA effort to enhance helicopter operations through improved mission reliability. The concept of "Zero/Zero" as well as the Forum were endorsed and enthusiastically supported by both the American Helicopter Society and the Helicopter Association International. The Forum was held in Phoenix, Arizona on August 11, 12, 13, 1987. The Forum was managed by Systems Control Technology, Inc. (SCT) as a part of NASA contract number NAS2-12478.

This Executive Summary is provided in order to give the reader an overview of the history, objectives and accomplishments of the Forum. It is also designed to provide a rudimentary understanding of the proceedings of each Working Group and the certification issues they discussed. Separate volumes are provided for those interested in a more complete description of the background research (Volume II) and the detailed descriptions, technical discussions and recommendations of each issue (Volume III).

It is important to note that certification in this Forum addressed the overall operations concept which included the aircraft, flight crew, ground facilities, navigation, air traffic control and communication systems.

Even though the terms "zero/zero", "IFR operations", "IFR Hover", etc., are used, it was established at the start of the Forum that the termination of an approach or hover (stationary over the ground) would be with outside reference. Outside reference is required to assure obstacle clearance and navigation to the landing site. This reference may be achieved either with the unaided eye (contact flight) or using augmented visual contact (enhanced electronic VFR, visionics, optronics, etc.).

Finally, while zero ceiling and zero visibility operation is an ultimate goal, it is probably not economically practical for "today's" civil operations. Therefore, a tiered set of very low visibility interim criteria (Airworthiness, TERPs, Heliports, etc.) should be the focus of near term efforts.

1.1 Objectives

The major objective of the Forum was to assemble an expert team of representatives from the helicopter manufacturing industry, avionics manufacturers, government regulators, researchers and consultants to discuss critical certification issues related to "Zero/Zero" rotorcraft operations. A secondary objective was to solicit recommendations from the experts on how to resolve those issues.

The deliberations of the Forum will be used to develop an "Action Plan" for the Rotorcraft R&D Program Office of the Federal Aviation Administration to use in planning and budgeting for both near and long term helicopter research and development in Zero/Zero helicopter operations.

1.2 Background

Helicopters have been approved for operations in Instrument Meteorological Conditions (IMC) under Instrument Flight Rules (IFR) since June 1960. Yet, today, there still are no IFR heliports which allow users to take full advantage of the helicopter's unique performance capability. Rather, helicopters operating in IMC are forced to operate as though they were fixed-wing aircraft, and pilots are constrained to standard FAA IFR airport operations, regulations and weather minima. The lack of available helicopter IFR landing sites currently imposes an operational limitation and an economic burden on helicopter operators in all types of missions from remote area fire fighting and search and rescue (SAR) to central business district (CBD) commerce and on-site emergency medical service (EMS). This systemic limitation manifests itself in three ways:

- Inhibits the development of a rapid, convenient business center to business center air transportation infrastructure.

- Constrains potential expansion of remote area markets for the industry.

- Reduces the economic potential (utilization rates and mission reliability) for current helicopter operations.

Present Visual Meteorological Conditions (VMC) landing requirements are predicated on helicopter size and performance and are limited, to a certain degree, by the imagination and skills of the pilot. In contrast, IFR heliport requirements are influenced by:

1. Aircraft Characteristics
   a. Performance
   b. Available avionics
   c. Man-machine interface including pilot workload
   d. Automatic Flight Control System coupling technology

2. Heliport Characteristics
   a. Size
   b. Available airspace (obstacle clearance)
   c. Ground guidance (intelligence) systems
   d. Available NAVAIDS & coverage
   e. Location (orientation) relative to the impact on required vehicle performance
   f. Prevailing winds and relationship to approach/departure paths as well as downdrafts from buildings
   g. Local natural or man made obstacles

3. Procedures
   a. Flying techniques
   b. Low altitude Air Traffic Control (ATC) procedures
   c. Surveillance and communication coverage

4. Regulations
   a. Operating
   b. Certification

5. Pilot Training & Proficiency

Individually each of these five elements have currently achieved at least a threshold of development and capability sufficient to meet the needs of helicopter zero/zero operations. Each is available for a prudent integration with other elements to achieve a near zero/zero helicopter landing capability within a reasonably sized landing site. What is needed is to identify the issues, interfaces and interdependencies (and sensitivities) of each of these five elements with the overall goal of developing economically, technologically and operationally feasible certification procedures.

Recognizing that a mixture of progressively increasing capabilities in each of these five areas exist today, a secondary goal becomes the development of integrated sets of these elements which relate to: handling qualities; navigation and guidance equipment; ground site design; air traffic control; and, instrument procedure development.

In addition, hardware capabilities are needed to provide sensors for on-board obstruction detection/avoidance, electronically aided visual guidance ("visionics") and other display and control requirements.

1.3 The Need for a Forum

The Certification Forum was an integral part of the Zero/Zero project plan for two reasons. First, the issues involved cover an extremely broad spectrum of requirements both technical and regulatory in nature. These include: airworthiness, engineering and operational requirements, Terminal Instrument Procedures (TERPs) criteria and economic cost/benefit considerations. Obviously, no single contractor or agency possesses this broad spectrum and depth of expertise, especially when the diverse interests of manufacturers, operators and regulators need to be considered with balanced objectivity.

Second, a Forum was required to review, critique, revise and homogenize the issues developed in the first half of the project. This was essential in light of the fact that they were developed through a series of literature searches, data review and one-on-one meetings with individuals who may have had a vested interest in the outcome of this analytical study.

1.4 Forum Attendees

The Forum attendees included 48 individuals from a broad spectrum of the helicopter community. Table 1.1 shows participation percentages of the FAA and industry with industry further divided to show representation perspective.

TABLE 1.1 FORUM PARTICIPANTS BY AFFILIATION

Participant Category	Percent of Total	
Federal Aviation Administration	36.	
Industry	64.	
Manufacturers		31.
NASA Researchers and Consultants		25.
Associations		6.
Aviation Press		2.

1.5 Forum Organization

The meeting was based on a common foundation of operator requirements, technological capabilities, the certification process and constraints to zero/zero implementation. The organizational format included plenary sessions, during which all attendees were exposed to the same material, and working groups organized to address specific problem areas. The Forum was conducted according to the following schedule:

August 11 (a.m.) - Initial plenary session with introduction and overview by FAA/APS-450, keynote addresses by the HAI (operator perspectives), AHS (technological perspectives), and FAA Southwest Region (certification perspectives).

A status and review of the Zero/Zero Helicopter Certification Project by SCT, Advanced Aviation Concepts and Starmark Corporation. Presentations by manufacturers (Sikorsky, Aerospatiale, and Sperry) and related research in low speed handling qualities (Systems Technology, Inc.) and electro-optical systems technology (DCS Corporation).

August 11 (p.m.) - Working Group organizational meetings and kickoff of discussions.

August 12 (a.m. & p.m.)- Simultaneous Working Group sessions to discuss critical issues, introduce new perspectives and develop a technical consensus.

August 13 (a.m.) - A short Plenary session to discuss key issues as a group. Final Working Group sessions to develop recommendations and consensus on work remaining for presentation at final Plenary Session.

August 13 (p.m.) - Final plenary Session to exchange findings between Working Groups and discuss recommendations with all participants. Closing Remarks and "where do we go from here" comments by APS-450.

Although the formal agenda and general Forum ended at 3:30pm on August 13, 1987, the organizing committee, Working Group chairmen and principals remained to discuss major findings, report organization, schedule, etc. The organizing committee, key participants and volunteers remained on-site through August 15, 1987 to prepare, in draft form, ideas and material for the Forum report.

TABLE 1.2 DETAILED ATTENDEE LIST

Category Key

Association - A	Consultant - C
Press - P	Manufacturer - M
NASA - N	FAA - F

Category	Name	Organization
C	Richard J. Adams	Advanced Aviation Concepts
M	Greg Ashe	McDonnell Douglas Helicopter Co.
M	Richard Balzer	Boeing Vertol
N	Vernol Battiste	NASA-Ames Research Center
F	Larry Bessette	FAA, AFS-350
F	Barry B. Billmann	FAA Technical Center, ACT-140
F	Richard A. Birnbach	FAA, AFS-210
F	Jack H. Burke	FAA, AAS-110
P	Keith Connes	Rotor & Wing International
F	Fred G. Cooper	FAA, AFS-250
C	William J. Cox	Aviation Systems Concepts, Inc.
M	Pascal Lefebvre du Prey	Thomson CSF
C	E. W. Endter	Systems Control Technology
F	Paul S. Faidley	FAA, ASW-270
C	Richard T. Flaherty	DCS Corporation
C	David L. Green	Starmark Corporation
M	Carl D. Griffith	Honeywell, Sperry DSD
M	Jake C. Hart	Aerospatiale Helicopter Corporation
M	Donovan L. Harvey	Bell Helicopter Textron
C	Roger H. Hoh	Systems Technology, Inc.
F	Jim S. Honaker	FAA, ASW-111
F	Peter Hwoschinsky	FAA/Helicopter Program Office, APS-450
A	Frank L. Jensen	Helicopter Association International
F	William R. Kessinger	FAA, AVN-210
F	Wayne Langston	FAA, ASW-170
F	William Larsen	FAA, Ames Research Center, AES-300
A	Glen Leister	Helicopter Association International
M	John W. Leverton	E.H. Industries Inc.
M	Paul J. Magno	Honeywell Inc., Sperry Flight Systems
M	Giffen A. Marr	Bell Helicopter Textron
M	Eugene C. McClain	McDonnell Douglas Helicopter Company
C	Roger P. McTighe	ESSEX Corporation
M	Richard Oracheff	Honeywell Inc., Sperry Flight Systems
F	Donald P. Pate	FAA AVN-210
F	LTC Lawrence P. Peduzzi	FAA, ARP-4
M	W. P. (Bill) Rea	McDonnell Douglas Helicopters Co.
M	Thomas G. Sandberg	Sikorsky Aircraft
F	Barry Scott	FAA - Ames Research Center, AES-300
N	Robert Jay Shively	Army/NASA
C	Jack Thompson	Systems Control Technology
F	Joseph J. Traybar	FAA Technical Center, ACT-330
M	Eugene L. Turner	Aerospatiale Helicopter Corporation
F	LTC Robert H. Vandel	FAA, ATO-320
F	Richard A. Weiss	FAA, Helicopter Program Office, APS-450
C	Howard A. Wheeler	RJO Enterprises Inc.
C	Mike W. Whitney	Hazeltine Corporation
M	Grady W. Wilson	McDonnell Douglas Helicopter Company
A	John Zugschwert	American Helicopter Society

1.6 Operational Requirements

The certification issues and recommended solutions summarized in this volume are designed to satisfy, as a minimum, the following operational requirements.

1. Fly the rotorcraft in a conventional way to intercept a precision glideslope (possibly not a constant angle).

2. Continue down the glideslope at a constant speed, or decelerating on a speed schedule, so as to arrive at a point on the glideslope with a speed which will permit the use of a modest decelerating flare maneuver to a hover.

3. Initiate a decelerating flare.

4. Avoid all obstacles by adhering to specified minimum safe altitudes for the specific landing site, or descent points that insure adequate separation.

5. Conclude the deceleration at the specified "target point".

6. Establish visual contact with the heliport environment either by direct viewing or by an electronically aided viewing system. If visual or electronic contact is not established, a missed approach should be initiated at this point.

As stated in requirement 6, the approach would be visual, in "difficult" weather, near buildings, wires and other obstacles. Obstruction detection/avoidance would be addressed as visual flight either with the unaided eye or with electronic vision aids.

The goal of these operational requirements is to enhance safety in difficult VMC operations such as Special VFR, Emergency Medical Services, etc.

1.7 Issues and Problems Discussed

Tables 1.3, 1.4 and 1.5 provide a complete summary of all the issues and problems addressed by participants at the "Zero/Zero" Certification Issues Forum. These are provided for cross reference purposes. Although the issues were initially numbered sequentially, they were subdivided and addressed individually by the two Working Groups and one plenary session as shown in the tables. It is for this reason the summary of proceedings of the Working Groups (Section 2.0) will address issues that are seemingly out of sequence.

Upon completion of deliberations on all issues, and when the recommendations of proposed solutions were documented, the Working Group Chairmen presented these results to the Final Plenary Session. In this way, a broader consensus from the entire group of attendees was obtained.

TABLE 1.3 CERTIFICATION ISSUES DISCUSSED IN WORKING GROUP A

Working Group A - Operations & Procedures

1. IMC Hover Capability, Pilot Training & Certification Requirements
2. IMC Autorotation - Training & Proficiency Requirements
3. Multi-directional Approach Path Requirements
5. TERP's Obstruction Clearance Planes
9. Ground/Airborne Equip. Requirement v. TERP's & Heliport Design Criteria
10. ATC Concepts for Low Altitude Random Routing (3D, 4D Guidance)
11. City-Center and Terminal Area Flight Corridors (Evaluate ATC Procedures)
12. Analysis of Necessary ATC Handbook (7110.65) Changes
13. Analysis of FAR Part 91 & 93 Applicability to Future Rotorcraft Operation
17. Pilot Training and Proficeincy Regulatory Requirements
18. Pilot Certification - Exam and Check Ride Requirements
26. Requirements for Autonomous Precision Approach Guidance Systems
27. IFR Heliport Marking and Lighting
33. Accuracy Criteria For Low Visibility Systems
35. CNS Requirements & Cost/Benefit Analysis for Coverage Below 2000' AGL
36. Analysis of FAR Part 71 for Low Visibility Certification Impact

TABLE 1.4 CERTIFICATION ISSUES DISCUSSED IN WORKING GROUP B

Working Group B - Airworthiness & Engineering

4. Helicopter Productivity Limits Under Current Regulations
6. Instrument Takeoff Abort Procedures
7. IMC Hover - Required Control Inputs Through Translational Lift
14. Acquisition and Maintenance Costs for On-Board Electronic Systems
15. Performance Penalties Associated with Current Regulations
16. Operating Cost Reduction with Improved Reliability/Mission Effectiveness
21. Minimum Required Cockpit Field for Visual Acquisition of Landing Environment
22. Minimum One Engine Inoperative (OEI) Performance Requirements
23. Requirement for a Highly Responsive Autopilot with Stable Heading Hold
28. Criteria for Airborne Imaging Technologies
29. Single-Engine vs. Multi-Engine Hover and Autorotation Performance
30. Effect of Engine Reliability Improvements on OEI Requirements
31. Requirements for Advanced On-board Navigation and Landing Systems
34. Requirements for All Weather Terrain and Obstacle Avoidance System
37. Acquisition and Operating Costs Associated with More Powerful Engines
39. Certification Procedures/Guidelines for Hover Through Translational Lift
40. Pitch Control In IMC Hover
41. Yaw Control at Low Airspeeds in Crosswind/IMC Conditions
42. Heading Control During Low Airspeed Maneuvers
43. Power Settling During Hover in IMC
44. Requirements for Engine Condition Monitoring
45. Subsystem Failure-Mode Redundancy Requirements
46. Requirements for Minimum IFR Lateral & Longitudinal Airspeed Components
47. Minimum Requirements for Abstract vs. Processed Data (Flight Director) Display System
48. Low Visibility Certification Requirements for Manual Backup for Automatic IMC Guidance
49. Identification and Specification of Minimum Flight Critical Systems
50. Simulation Needs for Certification

TABLE 1.5 CERTIFICATION ISSUES ADDRESSED IN PLENARY SESSION

8. ITO Abort Procedures - Emergency Landing Facility Requirements
19. Visual Cues for Attitude Reference During Low Speed, Low Visibility Flight
20. Accurate Ground Speed (or Closure Rate) Sensing and Display
24. Requirement for Accurate and Reliable Advanced Navigation & Guidance Systems
25. Advanced Systems and Displays for Terminal Guidance and Obstacle Avoidance
32. Requirements for Advanced Control Systems
38. Low Speed Stability and Control in IMC

1.8 Key Recommendations and Concepts

The following statements represent a few of the more substantive recommendations agreed upon by the Forum attendees:

A. Broad Consensus

1. An evaluation of the impact of excess performance resulting from spare engine power on the zero/zero certification issues was recommended. Excess performance, in this sense, means power held in reserve for emergency operations, not used to carry more personnel, payload or fuel. It was felt that many of the issues would be impacted by a 30-50% increase in performance. Some of the present requirements would be easier to meet and maybe some could be better identified so there is less room for argument or doubt. Once this has been determined, the issue of whether the power increase can be achieved economically (including the resulting benefit of relaxed certification criteria) should be addressed.

2. One key to the successful implementation of zero/zero may be the designation of a range of minima with very low ceilings and 25' to 2200' slant visual range. The last segment of the approach may be performed using "enhanced electronic VFR" capabilities available now. This concept is illustrated and described in Volume II.

3. The level of zero/zero capability may be tied to a trade-off between display sophistication, flight control system capabilities and handling qualities. Recent testing with a variable stability helicopter (FAA Technical Center with National Research Council (NRC) of Canada) has shown that low minima, decelerating approaches can be achieved with today's technology and without any giant strides in sophistication.

4. The need for improved low speed* handling qualities to achieve helicopter zero/zero** capability was a recurrent theme throughout the workshop. There was unanimous agreement that such handling qualities would be required to achieve a level of pilot workload which is acceptable in terms of safety. Satisfactory handling qualities can be obtained with today's stability augmentation systems (SAS). However, the minimum certification criteria and the trade-offs between handling qualities, workload and safety that maybe permitted need to be defined. Improved SAS capabilities may be required to satisfy safety and workload criteria.

5. From a certification viewpoint, there is a need to separate the issues associated with "see and avoid" from those associated with "see to land". There needs to be significantly more definitive research with regard to "see and avoid". At present this is an ill defined term and open to personal interpretation.

6. FAA should become an official member of ICAO Helicopter Operations (HELIOPS) commmittee. Currently, FAA participation is limited to providing observers to the committee.

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*For the Forum discussions, low speed is defined by the bucket of each rotorcrafts power required curve, by the ability of conventional airspeed systems, by static directional stability, etc.

**It was agreed that the term zero/zero is intended to encompass all low speed, low visibility IFR operations, with zero ceiling and zero visibility the ultimate goal.

B. "Zero/Zero" Approach Concepts

Two broad issues were discussed regarding "zero/zero" approach concepts. Theses were: low speed, low visibility approaches with the final segment conducted with visual contact; and, literal zero/zero in IMC. These represent the extremes of near term capabilities vs long, long term goals. As stated in the background, IFR certified helicopters have been around 27 years, yet no operational heliport today offers precision approach capability.

Near term low visibility efforts should be focused on minimum equipment, low levels of sophistication and the single engine aircraft as a starting point. These aircraft represent about 85% of the active civil helicopter fleet and, therefore, represent the largest group of potential beneficiaries of lower minima.

On the other hand, the long term "technology revolutions" should not be ignored. Considerable discussion and support for a new approach concept was evident during the deliberations at the Forum. Both working groups discussed the need for, and availability of, electro-optical or visionics systems. These systems may be required from an obstacle avoidance viewpoint to achieve the ultimate zero/zero goal. However, if they can be used to augment the pilot visual scan for obstructions, then why can't a segment of the approach be flown based on visual flight rules? These basic thoughts resulted in a proposed concept for an electronically augmented "visual" approach. The concept is described in detail in Volume II of this report.

C. Future Work Defined

Numerous unanswered questions, projects and test requirements were developed as a result of discussion and analysis of the 50 certification issues. These covered a wide spectrum of airworthiness, engineering, operational and regulatory concerns. They are presented in Volume III as "Recommendations", for each specific issue.

The concept of the FAA preparing for zero/zero before any manufacturer or operator has requested such certification is a revolutionary break with the traditional process. However, it appears appropriate in this case, considering the broad scope and number of issues that must be resolved. The following summarizes forum participant consensus on what issues must be addressed en route to zero/zero certification. They are not meant to indicate that the FAA has sole responsibility and/or the funding necessary to accomplish them. A companion document "Action Plan to Resolve Zero/Zero Rotorcraft Certification Issues", address time tables, milestones, tasks, responsibility allocation (FAA, NASA, Manufacturers, Operators, etc.) and prioritizes the issues.

An overall understanding of the depth and breadth of the work required to achieve zero/zero certification can be achieved by reviewing the following recommendations. For ease of reading the defined work has been broken down into seven Task Areas: Training, Procedures, Handling Qualities, Performance, Airborne Systems, Heliports, and Air Traffic Control.

1. Training

The basic work in the training area can be subdivided into Regulatory Changes, Human Factors and Training Methods. A well designed and correctly implemented training program would address the workload associated with low visibility approach and departure procedures for the minimum equipment/sophistication helicopter approved for low visibility operations, as well as training with new display/control systems and electro-optical or "visionics" systems. Several steps would expedite the development of both near and far term zero/zero operations.

First, a detailed task/workload analysis needs to be performed. This could be either a timeline task assessment or a simulator based evaluation.

Second, training materials and guidelines need to be developed based upon the zero/zero task analysis and supplemented by a review of current military (i.e. Nap of the Earth and Night Vision Goggles) training methods.

Third, the role of piloted simulation was briefly discussed. It was agreed that the state of the art of real-time piloted simulation is not well enough developed to allow certification of low speed IFR handling qualities, today. However, as a training aid, it was agreed that simulation has proven to be a valuable tool. The desirability of obtaining aerodynamic data for simulators during certification flight testing was discussed. A far term goal should be to develop this resource.

Finally, pilot certification and recurrency training requirements need to be developed based upon the first three tasks and flight tests performed at the FAA Technical Center and Canada's National Research Council. Specifically, training techniques should include back-side of the power curve glideslope tracking techniques.

2. Procedures

It was recommended that the potential advantages of procedures designed for low airspeed approaches be determined. This would include an establishment of definitions for rotorcraft categories, equipment, speeds, etc. Also, criteria for operations with special equipment, e.g. "visual enhancement" systems, are required.

The FAA must revise FAR Part 77 to include heliport requirements for advanced helicopter capabilities. This should include off-runway approaches at airports, business center heliports, and remote site requirements.

3. Handling Qualities

In order to conduct an IMC precision approach today an aircraft would have to meet existing IFR requirements. In other words, today, an IFR level of handling qualities (as defined by current criteria) would be a minimum. However, an interesting departure from this requirement was hypothesized at the Forum.

The hypothesis discussed was that a zero/zero approach capability may be achievable with vision aids which allow the pilot to operate as if the weather were VMC, as an alternative to, or in combination with, a deceleration to hover in IMC. While there was unanimous agreement that the conventional MLS/ILS approach to zero/zero would require improved aircraft handling qualities (compared to current VFR), there was considerable discussion related to the possibility that vision aiding would allow safe operations with "VFR handling qualities". Reference was made however to recent U.S. Army research in support of the LHX handling qualities specification which showed that:

- Current vision aids (night vision goggles and forward looking infrared [FLIR]) do not reproduce fine grained texture under most conditions.

- Increased aircraft stability is required at the very low airspeeds when the vision aid does not reproduce the fine grained texture (blades of grass, granularity of the surface, etc).

It is unlikely that vision aids capable of reproducing the necessary fine-grained texture will be available at some reasonable cost in the foreseeable future, and hence, there is a need for improved handling for either method of achieving zero/zero. It was agreed that the FAA should review these results to ascertain their relevance to civilian operations, and support where feasible further research.

Key handling qualities issues that should be resolved by the FAA were identified by the attendees. FAA representatives agreed to study these issues either through monitoring military research, or through FAA sponsored work. The issues are summarized below.

- Regulatory vs. advisory low speed handling qualities criteria. Manufacturers felt that criteria relating to specific dynamic response characteristics or displays should be advisory in nature. Regulations often inhibit innovation because there are too many gray areas in the control/display/pilot workload equation.

FAA personnel present concurred and further stated that they believed advisory low speed criteria was the only avenue open with technology advancing at its present rate.

- The minimum required stabilization should be identified. Specifically the following issues were found to be in need of further research:
  - Wing-low (heading hold) vs. turn coordination for low speed crosswind regulation.
  - Directional control. Improved directional control, and increased directional authority may be required for crosswind regulation in IMC to avoid control saturation.
  - Interaxis coupling, with emphasis on the collective-to-yaw coupling.
  - Airspeed and flight path control for operation on the back side of the power-required curve.
  - Reduction or elimination of the current emphasis on longitudinal static stability.
  - Identification of the minimum dynamic stability required for various levels of display sophistication and/or vision aiding.
  - Pitch attitude control at low speed. The pitch response tends to be nonlinear with speed, an effect which becomes more critical with increased horizontal tail area.
  - Fully coupled vs. manual approaches, and combinations involving split-axis control (e.g. collective coupled to glideslope and manual pitch and roll).

4. Performance

The basic issues are the power-to-weight ratio and excess performance available for takeoff and landing. Engine technology is available to provide about a 30% increase in horsepower for the same basic engine weight (i.e. LHX, T-800 technology vs current civil turbine engines). Improvements in engine weight fraction and airframe weight fraction should be augmented by additional gearbox/transmission weight fraction improvements to provide up to a 50% increase in excess performance in the next generation rotorcraft.

There is a need to develop concepts for the use and certification of short duration takeoff and landing power ratings. The development of these concepts should include integration and coordination of certification rules, operating rules, and airspeed concerns. Current FAA work and the forthcoming Notice of Proposed Rulemaking (NPRM) should be periodically revisited.

5. Airborne Systems

New or improved on-board systems to facilitate zero/zero certification cover a broad range of new technologies. These include sensors, displays, flight control systems, navigation/guidance/landing systems, obstruction detection systems and new visionics systems for low visibility operations.

In the sensor area low airspeed and groundspeed systems are needed to permit stable low speed maneuvering. Additional visionics sensors (e.g. millimeter wave radar (MMWR), forward looking infrared (FLIR), low light television (LLTV), carbon dioxide (CO_2) laser, or blended multi-sensor systems) may permit relaxation of IFR handling qualities certification criteria.

Display alternatives for low visibility certification include consideration of conventional, abstract and head-up formats. Additionally, integration of navigation and guidance information with visionics capabilities should be evaluated. Finally, the trade-offs between handling qualities, flight control system automation and display sophistication vs attainable approach minima need to be determined. Guidance material for low speed handling qualities and displays for both normal and degraded modes of operation should be developed.

Advanced navigation, guidance and landing systems need to be analyzed for on-airport, city center and remote sites. System specifications, flight inspection procedures, and reliability criteria need to be developed. Performance limits, accuracy values, and attainable flight technical error also should be determined as well as airspace requirements for all three applications. For remote sites, minimum required on-board equipment for IMC should be analyzed. (A basic definition of exactly what constitutes a "remote landing site" should be established).

Obstruction and terrain avoidance systems need to be reviewed for low speed, low visibility helicopter applications. Related military R&D should be reviewed. An FAA program to follow and evaluate related visual enhancement (sensor-display) program developments and all types of visualization systems (FLIR, MMWR, LLTV, etc.) should be investigated.

Present FAA research in the identification and specification of minimum flight critical systems (MFCS) should continue. All pertinent research work (DOD, NRC, NASA, industry, etc.) should be monitored to provide guidance on minimum systems, equipment, flying qualities and workload certification requirements.

6. Heliports

An FAA document, or an addendum to the current Heliport Design Guide, should be developed for heliports supporting zero/zero operations. The material should include both FAA and operator criteria.

Additional testing is required to determine marking standards and low visibility lighting alternatives for both high ambient light (city centers) and low ambient light (remote sites).

Determination of what is neccesary to achieve lower minima, should be provided for various approach NAVAIDS, lighting systems, weather services, etc.

7. ATC

All of the zero/zero technology and certification criteria will be useless without an ATC system designed to support its use. The work required in this area includes: determination of where low altitude and/or to-the-surface surveillance is needed; investigation of the applications and limitations of independent surveillance and/or fully automatic dependent surveillance; identification of areas where positive control to the surface is required from both a weather and an operations consideration; and the use of data link for communications with ATC.

In addition, regions where lower minimum altitude routing is practical and feasible should be determined. Currently minimum en route altitudes are often too high due to the limitations of communication, navigation, surveillance, etc.

Procedures for expeditious flow of helicopters to and between heliports and airports, and guidelines for VFR/IFR charting need to be developed. Standards for establishing heliport control zones are required.

2.0 SUMMARY OF PROCEEDINGS OF THE WORKING GROUPS

This section briefly summarizes the major recommendations of each of the Working Groups.

2.1 Working Group A: Operations and Procedures

- Purpose of the group.

  This group was tasked with analyzing and making formal recommendations for operational and procedural changes necessary to achieve zero/zero certification. Their work focused in the areas of pilot training, TERPs, ATC, Navigation/Guidance and Landing Systems.

- Group Chairman was Mr. Donald P. Pate of the FAA's Flight Standards Development Branch, AVN-210.

- Working Group Technical Staff was comprised of:

Mr. Barry R. Billmann	FAA Technical Center, ACT-140
Mr. Jake C. Hart	Aerospatiale Helicopter Corporation
Mr. William J. Cox	Aviation Systems Concepts, Inc.

- A List of Participants Affiliations and Telephone Numbers is provided in Table 2.1.

TABLE 2.1 WORKING GROUP A PARTICIPANTS

	PARTICIPANT	AFFILIATION	PHONE
1.	Jack H. Burke	FAA - AAS-110	(202) 267-8763
2.	William J. Cox	Av. Sys. Concepts, Inc.	(703) 642-2177
3.	Glenn Leister	Helicopter Assoc. Int'l	(703) 683-4646
4.	Greg Ashe	McDonnell Douglas	(602) 891-3773
5.	Pascal Lefebvre du Prey	Thomson CSF (International)	(331) 46847187
		(NY office)	(212) 956-7300
6.	William Larson	FAA/Ames Tech Office	(415) 694-6380
7.	LTC Robert H. Vandel	FAA - ATO-320	(202) 267-9340
8.	Jake C. Hart	Aerospatiale	(214) 641-3565
9.	Peter V. Hwoschinsky	FAA - APS-450	(202) 267-8531
10.	William R. Kessinger	FAA - AVN-210	(405) 686-4164
11.	Fred G. Cooper	FAA - AFS-250	(202) 267-3772
12.	Paul S. Faidley	FAA - ASW-270 (AEG)	(817) 624-5272
13.	Donovan L. Harvey	Bell Helicopter	(817) 280-2209
14.	Vernol Battiste	NASA - Ames Research Center	(415) 694-6249
15.	R. Jay Shively	Army Aeroflight dynamics	(415) 694-6249
16.	Mike W. Whitney	Hazeltine Consultant	(516) 266-5623
17.	Howard A. Wheeler	RJO Enterprises, Inc.	(301) 731-6862
18.	John W. Leverton	E.H. Industries	(703) 486-8000
19.	Barry R. Billmann	FAA Technical Ctr., ACT-140	(609) 484-6608
20.	Donald P. Pate	FAA - AVN-260	(202) 646-4164
21.	Frank L. Jensen	Helicopter Assoc. Int'l	(703) 683-4646
22.	Richard A. Weiss	FAA - APS-450	(202) 267-8535
23.	Barry Scott	FAA/Ames Tech Office	(415) 694-6380

- Scope: The group analyzed 16 specific issues as listed previously in Table 1.3. A grouping of the issues discussed by major Task Area is provided for ease of reference in Table 2.2.

TABLE 2.2 TASK AREA GROUPING OF OPERATIONS & PROCEDURES ISSUES

Task Area	Issue Reference Numbers
1. Training	1, 2, 17, 18
2. Procedures	3, 5, 9, 27
3. ATC	10, 11, 12, 13, 35, 36
4. Navigation & Guidance	26, 33, 35
5. Heliports	3, 27

2.2 Summary of Working Group A Issues and Major Recommendations (Selected subset of all recommendations from Volume III)

Issue No.	Title	Major Recommendation(s)
1	IMC Hover Capability, Pilot Training and Certification Requirements.	1) Identify pilot tasks 2) Determine display and flight control requirements 3) Investigate human factors elements in system design 4) Review regulatory changes required to certify pilots/ operations/systems
2	IMC Autorotation - Training & Proficiency Requirements	Establish standards to certify airmen for zero/ zero operations.
3	Multi-directional Approach Path Requirements	Revise FAR Part 77 to account for advanced approach capabilities.
5	TERPs Obstruction Clearance Planes	Investigate pilot performance for operations at lower airspeeds, maneuvering, and non-standard rate of turn.
9	Ground/Airborne Equipment Requirement vs. TERPs & Heliport Design Criteria	Determine CAT II and lower accuracy "window" requirements for heliports. For heliports using MLS requirements exist to specify the minimum physical size, evaluate the need for a field monitor and determine critical or sensitive areas.

Issue No.	Title	Major Recommendation(s)
10	ATC Concepts for Low Altitude Random Routing	Investigate applications and limitations of two concepts: manual dependent surveillance and fully automatic dependent surveillance.
11	City Center and Terminal Area Flight Corridors (Evaluate ATC Procedure)	Identify where positive control to the surface from both a weather and operations sense is needed.
12	Analysis of Necessary ATC Handbook (7110.65) Changes	1) Review local procedure/policies for input to air traffic control handbook changes. 2) Develop standards for VFR/IFR charting guidelines for low altitude helicopter operations.
13	Analysis of FAR Part 91 & 93 Applicability to Future Rotorcraft Operation	Establish standards for heliport control zones.
17	Pilot Training and Proficiency Regulatory Requirements	1) Establish pilot training guidelines/educational materials for low visibility approach/departure 2) Evaluate the requirements for new displays/control systems/"visionics" 3) Determine feasibility of simulator training for "new" technology & low visibility operations.
18	Pilot Certification - Exam and Check Ride Requirements	1) Establish pilot certifixation and recurrency requirements. 2) Develop an advisory circular appendix for for helicopter IFR flying.
26	Requirements for Autonomous Precision Approach Guidance System	1) Review & evaluate DOD/USCG methods for applicability. 2) Determine on-board equipment required to operate IMC to remote site.

Issue No.	Title	Major Recommendation(s)
27	IMC Heliport Marking and Lighting	Require testing to determine requirements for low visibility lighting/marking standards.
33	Accuracy Criteria for Low Visibility Systems	1) Establish navigation system tolerance limits for lower than CAT II. 2) Determine along track accuracy and granularity requirement for low airspeed operations. 3) Determine MLS critical areas (as installed at the heliport). 4) Examine other navaids for possible application to low visibility operations.
35	CNS Requirements & Cost/Benefit Analysis for Coverage Below 2000' AGL	1) Determine where to-the-surface surveillance is required. 2) Investigate use of data-link communications for ATC.
36	Analysis of FAR Part 71 for Low Visibility Certification Impact	Determine areas where minimum altitude routing can be established using Loran-C or equivalent.

2.3 Working Group B: Airworthiness & Engineering

- Purpose of the Group

  To reach agreement of participants on certification issues dealing with airworthiness, handling qualities and engineering changes. Where possible to recommend certification changes to reflect group consensus and to submit recommendations for further study, research or testing where it is deemed appropriate.

- Group Chairman was Mr. Jim S. Honaker of the FAA's Rotorcraft Standards Staff in the Southwest Region Certification Directorate, ASW-111.

- Working Group Technical Staff was comprised of:

  Mr. Joseph J. Traybar — FAA Technical Center, ACT-340
  Mr. David L. Green — STARMARK Corporation
  Mr. Thomas G. Sandberg — Sikorsky Aircraft

- A list of participants is provided in Table 2.3.

TABLE 2.3 WORKING GROUP B PARTICIPANTS

	PARTICIPANT	AFFILIATION	PHONE
1.	Richard J. Adams	Advanced Aviation Concepts	(609) 259-0726
2.	Thomas G. Sandberg	Sikorsky Aircraft	(203) 381-6187
3.	David L. Green	STARMARK Corporation	(703) 685-4250
4.	Joseph J. Traybar	FAA Technical Center, ACT-330	(609) 484-4286
5.	Jim Honaker	FAA - ASW-111	(817) 624-5109
6.	Roger H. Hoh	Systems Technology Inc.	(213) 679-2281
7.	Wayne Langston	FAA - ASW-170	(817) 624-5274
8.	Grady W. Wilson	McDonnell Douglas	(602) 891-2445
9.	Barry C. Scott	FAA - NASA Ames, AES-300	(415) 694-6379
10.	Larry Bessette	FAA - AFS-350	(202) 267-8177
11.	W. F. (Bill) Rea	McDonnell Douglas	(602) 891-6523
12.	Eugene C. McClain	McDonnell Douglas	(602) 891-2329
13.	Giffen A. Marr	Bell Helicopter	(817) 280-2193
14.	Eugene L. Turner	Aerospatiale	(214) 641-3513
15.	Richard A. Birnbach	FAA - AFS-210	(202) 479-0285
16.	Richard T. Flaherty	DCS Corporation	(703) 683-8790
17.	Carl D. Griffith	Honeywell/Sperry	(505) 828-7870
18.	Richard Balzer	Boeing Vertol	(215) 591-7070

- Scope: The group analyzed 30 issues as listed previously in Table 1.4. Due to the larger number of issues, the working group defined related issues as they progressed and cross referenced recommendations where applicable. A grouping of the issues discussed by Major Task Area is provided for ease of reference in Table 2.4.

TABLE 2.4 TASK AREA GROUPING OF AIRWORTHINESS & ENGINEERING ISSUES

Task Area	Issue Reference Numbers
1. Displays	48
2. Sensors/Systems	23, 28, 44, 46, 47
3. Power	21, 29, 30, 45
4. Handling Qualities	6, 7, 40, 41, 42
5. Obstruction Detection	34
6. Economics/Productivity	4, 14, 15, 37
7. Heliports	16
8. Helicopter Design	21
9. Navigation/Guidance	24, 31,
10. Procedures	43
11. Certification	39, 47, 48, 49
12. Simulation	50

2.4 Summary of Working Group B Issues and Major Recommendations (Selected subset of all recommendations from Volume III)

Issue No.	Title	Major Recommendation(s)
4	Helicopter Productivity Limits Under Current Regulations	A study is needed to determine the regulatory framework for excess power capacity. ADL should conduct the study and complete it within the next 5 years. APS-450 should lead the work related to excess power, the impact of more than two engines, and regulatory credit impacts.
6	ITO Abort Procedures	See Issue #7
7	IMC Hover - Required Control Inputs Through Translation Lift	Southwest Region will monitor existing R&D programs (FAA, NRC, NASA, Army) and testing,and develop regulatory changes as dictated by the data. The Region will also request additional work in low speed handling qualities as required.

Issue No.	Title	Major Recommendation(s)
14	Acquisition and Maintenance Costs for On-Board Electronic Systems	This is a "market place" subject to be treated by individual operators, not an issue for future study.
15	Performance Penalties Associated with Current Regulations	See Issue #4 & Combine
16	Operating Cost Reduction with Improved Reliability/Mission Effectiveness	See Issue #4 & Combine
21	Minimum Required Cockpit Field of View for Visual Acquisition of Landing Environment	Southwest Region will include guidance information in an AC rather than dictate design or address changes in the regulations.
22	Minimum OEI Performance Requirements	As relates to minimum OEI performance, a study should be conducted to coordinate certification rules, operating rules and airspeed matters. Also see issue #4 and combine.
23	Requirement For Highly Responsive Autopilot with Stable Heading Hold	Combine with Issue #7.
28	Criteria for Airborne Imaging Technologies	See Issue #34.
29	Single-Engine vs. Multi-Engine Hover & Autorotation Performance	Combine with Issue #4.
30	Effect of Engine Reliability Improvements on OEI Requirements	Combine with Issue #4.
31	Requirement for Advanced On-board Navigation and Landing Systems	The FAA should define the program that would be required to get the system approved and airspace requirements defined. Future actions should depend upon the results of the program definition.

Issue No.	Title	Major Recommendation(s)
34	Requirements for All Weather Terrain and Obstacle Avoidance System	The FAA (APS-450) should fund ACT-330 to follow and evaluate related visual enhancement (sensor-display) program developments and support other related projects. All types of visualization systems (FLIR, MM wave radar, LLTV, etc.) should be investigated. Civil, DOD and NASA efforts should all be included.
37	Acquisition and Operating Costs Associated with More Powerful Engines	See Issue #4.
39	Certification Procedures/Guidelines for Hover Through Translational Lift	Combine with Issue #7.
40	Pitch Control In IMC Hover	Pitch attitude trim and transient behavior should be included as part of the low speed handling qualities investigation. Combine with Issue #4.
41	YAW Control at Low Airspeeds in Crosswind/IMC Conditions	The FAA should include yaw controlability in the minimum handling qualities and display studies with consideration for identifying guidance relative to the maximum allowable yaw oscillatory characteristics and the need to avoid periodic departures in yaw during the approach and the post-approach IMC hover phase. Combine with Issue #7.
42	Heading Control During Low Airspeed Maneuvers	See Issue #41. Combine with Issue #7.

Issue No.	Title	Major Recommendation(s)
43	Power Settling During Hover in IMC	FAA should provide guidance material relating to steep approaches which identifies issues and requirement to avoid vortex ring state.
44	Requirements for Engine Condition Monitoring	Continue to support work on health monitoring systems.
45	Subsystem Failure-Mode Redundancy Requirements	Premature issue at this time, retain for future work and combine with #4.
46	Requirements for Minimum IFR Lateral & Longitudinal Airspeed Components	Combine with Issue #20.
47	Minimum Requirements for Abstract (computed) vs Processed Data (Flight Director) Display Systems	1) FAA should not make regulations that preclude abstract data display systems. Abstract data display system studies (by industry and NASA) should be supported and advisory circular guidance provided, when available, for rotorcraft. 2) FAA should also establish an FAA and industry team to provide standardization guidance for abstract data displays.
48	Certification Requirements for Manual Backup of Automatic Guidance During Low Visibility Operations	Combine with issue #4.
49	Identification and Specification of Minimum Flight Critical Systems	1) Present FAA research activities should continue. Southwest Region should continue to monitor all pertinent research and work with DOD, NRC, NASA and industry to

49	Cont.	provide guidance on minimum systems, equipment, flying qualities and workload certification requirements. 2) FAA headquarters should continue funding in these areas. 3) Southwest Region should incorporate airworthiness regulatory changes and amendments as indicated by the results and conclusions.
50	Simulation Needs for Certification	Helicopter manufacturers should work with simulator manufacturers & researchers to provide necessary data during development of new designs to produce simulators suitable for training and aircrew certification for "zero/zero" operations.

2.5 Summary of Joint Working Group Issues
(Selected Subset of all Recommendations from Volume III.)

Issue No.	Title	Major Recommendation(s)
8	ITO Abort Procedures - Emergency Landing Facility Requirements	Alternatives to facility requirements should be investigated. These should include: 1) Developing sensors and displays for replication of CAT A instrument takeoff abort procedures. 2) Survey of heliport egress routes (what is out there) and what percent of accidents occur due to aborted takeoffs.

Issue No.	Title	Major Recommendation(s)
		3) Operating procedures for VFR in IMC with electronic visual aids should be developed.
19	Visual Cues for Attitude Reference During Low Speed, Low Visibility Flight	Survey and analysis of state-of-the-art in displays should be performed. This should include: 1) Innovative artificial horizon. 2) Optronics and visionics systems. 3) Head-up displays. 4) Computer generated images.
20	Accurate Ground Speed (or Closure Rate) Sensing and Display	1) Continued studies are needed for sensors, displays and definition of limits. 2) Investigation of synthetic data should be analyzed to "aid" during short sensor dropouts.
24	Requirement for Accurate & Reliable Advanced Navigation & Guidance System	1) System specifications and flight inspection procedures should be developed. 2) The FAA Technical Center should investigate requirements and test procedures. 3) Accuracy values for various windows known for fixed-wing need to be developed for helicopter decelerating approaches.
25	Advanced Systems & Displays for Terminal Guidance & Obstacle Avoidance	See Issue #24 & Combine.
32	Requirements for Advanced Control Systems	Systems concepts, specifixations and performance limits need to be analyzed.
38	Low Speed Stability and Control in IMC	See Issue #7.