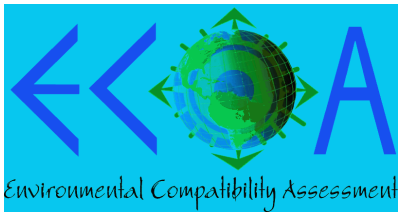

REPORT

ON THE

NASA ENVIRONMENTAL COMPATIBILITY WORKSHOPS

CONDUCTED FOR NASA CONTRACT

NASW – 4967

SAIC Proposal Number 06-6090-71-0980-009 (R1), December 19, 1997

Submitted by

SAIC/ATSO

1213 Jefferson Davis Highway, Suite 1500

Arlington, VA 22202

703-414-3800

Foreward

The NASA Office of Aeronautics and Space Transportation Technology (OASTT) requested that SAIC assist them in assessing its environmental research and technology programs relative to the "Three Pillars for Success" enabling technology goals to determine whether NASA's goals meet the needs of the aviation and environmental communities.

In support of this assessment, SAIC was requested to perform the following tasks:

- Support OASTT and the NASA Environmental Compatibility Assessment (ECoA) Core Team in developing a consensus within the aviation and environmental communities for NASA's environmental technology goals in sufficient fidelity to support effective planning of NASA environmental programs.

- Utilize the NASA enabling Technology Goals from the "Three Pillars for Success," along with guidance from the ECoA Core Team on strawman scenarios and metrics, to plan and conduct a series of workshops.

- Prepare reports for NASA approval on the proceedings of each of the workshops and the overall activities.

The following report's Executive Summary, workshop agendas, minutes, and summaries have been reviewed and commented on by ECoA Core Team members, as well as a number of the workshop participants. Their comments have been incorporated into the individual components of this final report. This coordination on the draft report took place during August-September, 1998 and the final report preparation and coordination culminates with the delivery of this report. Follow-on work resulting from the recommendations of the workshops will be included in a separate report which will be developed and delivered in the January-March, 1999 time frame.

Workshop Plan:

In preparation for the first workshop the ECoA and SAIC met and developed a Workshop Plan. This plan in the form of a schematic was presented to the participants at the first workshop. After each of the workshops, the ECoA Team and SAIC met and discussed lessons learned. Following these discussions the plan was adjusted and modified. These adjustments represented fine-tuning and permitted NASA to take full advantage of the opportunities to exchange information and views with the participants. The overall concept for the workshops and the objectives were maintained throughout. The schematic representing the final workshop plan follows this Forward.

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List of Acronyms (LOA)

AIAA	Aerospace Industries Association of America
ANC	Active Noise Control
ARC	Ames Research Center
ASAP	As Soon As Possible
AST	Advanced Subsonic Transport
ASTTAC	Aeronautics and Space Transportation Technology Advisory Committee
ATA	Air Transport Association
ATC	Air Traffic Control
ATM	Air Traffic Management
CAEP	Committee on Aviation Environmental Protection
CCAP	Center for Clean Air Policy
CFC	Chlorofluorocarbons
CNS/ATM	Communications, Navigation, and Surveillance/Air Traffic Management
CO_2	Carbon Dioxide
CONUS	Continental United States
CTAS	Center Tracon Automation System
DAC	Dual Annular Combustor
dB	Decibel
DFRC	Dryden Flight Research Center
DFW	Dallas-Fort Worth
DNL	Day-Night Level
DOE	Department of Energy
DOT	Department of Transportation
ECoA	Environmental Compatibility Assessment
EDF	Environmental Defense Fund
EDP	Expedite Departure Planner
EPA	Environmental Protection Agency
EPNdB	Effective Perceived Noise Level (decibels)
FAA	Federal Aviation Administration
FAST	Final Approach Spacing Tool
GAMA	General Aviation Manufacturers Association
GCC	Global Climate Change
GSFC	Goddard Space Flight Center
HSCT	High Speed Civilian Transport
ICAO	International Civil Aviation Organization
LAQ	Local Air Quality
LARC	Langley Research Center
LAX	Los Angeles International Airport
LERC	Lewis Research Center
LTO	Landing-TakeOff
MEMS	Micro Electric Mechanical Systems
MIT	Massachusetts Institute of Technology
NACA	National Advisory Committee for Aeronautics
NASA	National Aeronautics and Space Administration
NGO	Non-Government Organization
NOAA	National Oceanic and Atmospheric Administration
NOISE	National Organization to Insure a Sound Environment
NOx	Nitrous Oxide

NRDC	Natural Resources and Defense Council
OSTP	Office of Science and Technology Policy
P&W	Pratt and Whitney
PEM	Proton Exchange Membrane
PM	Particulate Matter
QCSEE	Quiet, Clean, Short-Haul Experimental Engine Program
R&D	Research and Development
ReCAT	Reduced Cost of Air Travel
SAIC	Science Applications International Corporation
SeaTac	Seattle-Tacoma International Airport
SMA	Surface Movement Advisor
SO_2	Sulfur Oxide
SOFC	Solid Oxide Electrolyte Fuel Cells
STOL	Short Takeoff and Landing
TRACON	Terminal Radar Approach Control
TRL	Technology Readiness Level
UDF	Unducted Fan
VOC	Volatile Organic Compound

Environmental Compatibility Assessment Workshops
Executive Summary

Introduction:

Three key trends-- the rapid growth in air traffic, suburban sprawl and growing popular concern for the environment-- have combined over the last decade to raise concerns about the impact of aviation on the environment. Continuing growth in air traffic has forced many airports to expand their operational capacity by adding terminals, runways and support facilities to accommodate the growing numbers of passengers and the increased volume of freight. At the same time, the suburban areas of many cities began extending further out from the cities. Airports that were once on the outer fringes of the cities that they served found themselves facing residential communities that objected to the increased air traffic and airport expansion plans. Many of these communities objected to the noise and emissions that increased air traffic and airport expansion had imposed upon their neighborhoods, and reacted by becoming increasingly vocal in their opposition, and by carrying their protests to the courts and their elected officials.

Recently political leaders around the world have become concerned about environmental impacts that crossed national and regional boundaries. These concerns about global impacts were evidenced in the international conferences held in Rio de Janeiro, Brazil and in Kyoto, Japan. Pressure to address the more global issues has increased significantly and concern about the destruction of ozone and global warming still continues to mount. Aviation, which previously had been primarily viewed as a local noise and air quality problem, is now faced with growing scrutiny regarding the potential global impact of its emissions. While the specific goals or criteria regarding these emissions has not been established, it is clear that aviation is under pressure to make some contribution to the reduction of greenhouse gases and their precursors.

Understanding the impact and finding realistic solutions to these problems at both the local and global level is essential. Aviation has always been important to the United States. As a nation we view our leadership in the field of aviation and aviation technology as a matter of national prestige. Aviation is also a critical component of our economy. Airplanes and aviation products are the leading manufacturing export for the United States and are critical to our balance of trade. In addition, air travel for business and pleasure has become an integral part of the global economic and social system. Clearly, solutions have to be found that accommodate the growth of the aviation industry while minimizing the impact on the environment.

In 1995 the White House National Science and Technology Council published a report entitled Goals for a National Partnership in Aeronautics Research and Technology. The report concluded that, "Environmental issues are likely to impose the fundamental limitation on air transportation growth in the 21st century." Two years later the National Research Council in a report entitled, Maintaining U. S. Leadership in Aeronautics, discussed the challenges facing aviation in the United States and noted, "The public will continue to demand reductions in environmental damage and reductions of acoustic noise over urban areas." The report recognized NASA's mission in continuing our leadership position and noted, "NASA has been charged…to develop an integrated national strategy and priorities assessment for civil aeronautics."

NASA's Three Pillar Goals:

As the agency responsible for maintaining the United States technological leadership in commercial aviation, NASA responded to the challenge by issuing its Three Pillars for Success, which include a set of environmental goals for commercial aviation. The Goals call for the reduction of perceived noise level for future aircraft by a factor of two from today's subsonic aircraft within ten years. In addition, noise levels are to be reduced by a factor of four within 25 years. Emissions of future aircraft are to be reduced by a factor of three within ten years and by a factor of five within 25 years.

To achieve these Goals, the NASA Environmental Compatibility Assessment (ECoA) Core Team was created to develop program recommendations to NASA management. The first task of the NASA Core Team was to assess the feasibility of achieving the Three Pillars' environmental Goals through ongoing research and technology development programs. In addition to recommending additional activities, the team was to identify technical solutions and suggest research priorities. The final challenge for the Core Team was to build consensus and advocacy among the community of interests that included the aviation manufacturers, airlines, airport operators, the environmental community and involved federal agencies. It was this last challenge that led to the NASA Environmental Compatibility Assessment Workshops.

Establishing the Workshops:

In the spring and summer of 1998, NASA convened a series of three workshops as part of the Environmental Compatibility Assessment. The workshops brought together representatives from airframe and engine manufacturers, airport and airline operators, environmental and community organizations, university researchers, consultants, state and federal agencies, and the White House. The workshops were held at "neutral sites" rather than at NASA facilities. In addition, each workshop was held in a different part of the country to attract a broader group of participants. The first meeting was held in Atlanta, Georgia March 17th through 19th; the second in Cleveland, Ohio May 19th through 21st; and the third in Monterey, California from July 7th through 9th.

Attendance at the workshops ranged from 85 to over 100 participants. Staff support was provided by SAIC and a neutral chairman presided over the workshop meetings.

The workshop series was to be a building process wherein the findings and accomplishments of the first workshop would serve as the point of departure for the second workshop to build upon. Subsequently the first and second workshops would be the foundation for the final workshop. The overall concept called for the first workshop to provide shared learning experiences among the diverse group of participants. The primary objective was to define the problem in terms of the environmental issues that were most likely to impose basic limitations on aviation's growth and to identify the technical challenges to eliminate these problems. The second workshop was to review the likely scenarios, analyze the gap between the scenarios and the Goals, and then to create new concepts that would become part of strawman roadmaps designed to achieve the Three Pillars' environmental Goals. The final workshop would refine the roadmaps, reassess the gap analysis, identify research priorities, and chart the way forward. Participant relationships established during the workshop process were considered to be an important element of the continuing NASA Research and Technology Program.

To focus the efforts of the workshop participants, NASA posed four general questions at the first workshop meeting:

1) What are the impacts of aviation noise and emissions on the environment?
2) How do you believe these may affect the growth of aviation?
3) Must the growth of aviation lead to increased environmental impacts?

4) What is the relationship of the NASA noise and emissions goals to aviation's impact on the environment?

These questions provided the participants with a number of different perspectives from which to consider the environmental problems of aviation. It was not intended that the questions be rigorously answered but only to serve as signposts to indicate the general focus of the workshop efforts. During the series of workshops, these questions were periodically revisited to take stock of the progress of the group and to steer the discussions back on track.

It was felt by many that the third question was probably the key. In effect it asked, "Is there a better way? Or what might new technologies contribute to resolving the problem?"

First Workshop:

The primary theme of the first workshop was to define the problem. The participants divided into two breakout groups. One focussed on issues related to noise, while the other group examined the issues associated with emissions. This method of organization tended to focus participants on one or the other of these problem areas. (This approach was used for all three workshops however; the participants would meet periodically in plenary format to exchange information and views.)

The Noise Breakout Group identified a number of issues that they believed needed to be addressed. There was concern over the Noise Goals as stated in the Three Pillars. These Goals were cast in terms of research objectives. The difficulty arose when these goals were juxtaposed to the problem, that is, the perceived noise near the airport boundary or under aircraft flight paths. There was also the problem of a single event versus the cumulative effect of repeated noise at different times of the day or night. The choices made for the appropriate noise metrics were considered critical in evaluating the community impact as well as for certification and regulation criteria. Compounding this problem was the generally held opinion that the current noise models were not adequate for either measuring or predicting perceived noise levels. The Group recommended that improved metrics and models to measure and forecast noise levels were needed.

The Breakout Group opined that careful planning would be needed to balance near and far-term research with basic and focused research. Finally, it was important that issues surrounding the use of new technology, such as certification or regulation, be addressed in the NASA strategic plans.

In addition to the issues identified by the Noise Group, a number of technology concepts to reduce aircraft noise levels and achieve public acceptance were identified. These covered several different approaches, such as research related to unconventional airframes and engines, source noise reduction and adaptable designs. In the opinion of the Group, there was considerable potential to reduce noise through the use of systems approaches and operational changes in flight patterns, taxiing, and ground operational procedures.

The Emissions Breakout Group also identified a number of issues that needed to be addressed. First among these was the need to improve the understanding of atmospheric chemistry and modeling techniques. They felt that the current levels of basic scientific knowledge regarding cause and effect were insufficient for understanding the effectiveness of the various technical fixes. However, they believed that protection of the ozone layer should focus on reducing cruise emissions of nitrous oxides (NOx) and sulfur aerosols. They called for improved methods to evaluate trade-offs between various emissions reduction strategies. The application of a systems approach to analyze the benefits of new technologies, operational improvements and procedural changes was also noted. Finally, the Emissions Group called for a plan to balance evolutionary and revolutionary research.

The Emissions Group also identified a number of mitigation approaches that were believed to have promise. They believed it was important to look beyond fossil fuels for the long-term options. They proposed that the NASA technology strategy seek to minimize local air quality problems by emphasizing reductions in NOx in the landing and takeoff cycle. The Group recommended efforts to improve fuel efficiency toward its practicable and feasible limits to minimize global climate change. The Emissions Group also emphasized the need to consider affordability and economic feasibility in evaluating technology options.

During the first workshop, the plenary group discussed the need to agree on some basic points of departure that would guide the discussions of the workshop. After some discussion it was generally agreed that the following three principles applied.

1) It was not the objective of the participants and the groups represented at this workshop to limit the growth of aviation, but rather to limit the impact of aviation's growth on the environment.
2) All stakeholders need to share the burden of developing and implementing solutions.
3) Acceptable levels of noise and emissions must be clearly defined.

At the wrap up session for the first workshop, the participants requested that information in the form of reports or briefings on a number of topics be provided at the second workshop.

Second Workshop:

The theme of the second workshop was to exchange information and discuss concepts. The information exchange began with briefings that had been requested at the first workshop. These included topics, such as global climate change, innovations in air traffic management and its impact on aircraft emissions, and zero-emissions aircraft. The Federal Aviation Administration (FAA) gave three presentations: one regarding its role in certification and regulation and future International Civil Aviation Organization (ICAO) work programs; another addressing the importance of environmental research and the coordination of FAA and NASA programs; and a third which reviewed the CNS/ATM (Communications, Navigation, Surveillance/Air Traffic Management) Program.

The scenarios describing the likely future growth in aviation, the levels of emissions and noise under varying growth assumptions, technology advances, and the composition of the airline fleet were presented by NASA. These were followed by a discussion of the gap analysis. The gap was defined as the difference between existing NASA research programs and the Three Pillars Goals.

The challenge facing NASA was to develop a "roadmap", that is, a plan to reach the objectives set forth in NASA's Three Pillars' Goals as stated previously. The roadmaps would identify the specific activities of the research and technology development efforts. With this background, participants returned to the Emissions and Noise Breakout Groups and discussed technical concepts that could help close the gap. During these sessions, the participants discussed new concepts and enabling technologies to meet these challenges. These inputs were eventually incorporated into strawman roadmaps.

The Emissions Breakout Session offered a number of suggestions including ultra-high-bypass propulsion and ultra-high-temperature cores; hybrid engine systems; metal/ceramic/polymer matrix composites; hydrogen fuel cells and several others. A complete listing of the concepts and technologies proposed by each of the Emissions Subgroups (Airframe and Propulsion) is contained in the minutes for the second workshop.

The Noise Breakout Group addressed source noise reduction, modeling and operations. They identified four broad technology systems that included propulsion systems, airframes, air space operations, and integration

and modeling. For each of these areas, they focused on the two time frames identified in the Three Pillars' Environmental Goals, the years 2007 and 2022. A broad list was generated for each of the technology areas and each of the time horizons.

Each of the Breakout Groups expressed similar ideas in terms of where NASA needed to go and what steps should be taken next. These included the following points. System studies were needed to evaluate and prioritize proposed technologies. They should include cost-benefit analyses and the establishment of figures-of-merit for grading the technology recommendations. Each of the technology options should be mapped into the roadmaps to identify expected potential benefits. Appropriate Technology Readiness Levels (TRLs) also need to be defined and worked into the gap analysis. Finally, there was a need to understand which emissions or noise technology options have potentially negative impacts on one another and which work synergistically.

The participants also expressed concerns that the "wind down" of the NASA Advanced Subsonic Transport (AST) Program and the decrease in funding would occur before new research programs could be started. This could result in a breakup of the research teams and the disruption of program continuity.

At the close of the second workshop NASA agreed to review and critique the proposed concepts and strawman roadmaps and report back to the participants at the third workshop.

Third Workshop:

The theme of workshop three was feedback. This included NASA feedback on the strawman roadmaps, gap analysis and the participants' feedback to NASA on key aspects of ECoA and the NASA Goals.

The NASA critique and reassessment of the strawman roadmaps and the gap analysis was presented. The critique identified the contributions to noise and emission reductions that could be anticipated from the ongoing AST Program and the estimated contribution that would be needed from other activities if the NASA Goals were to be achieved. The roadmaps indicated where these reductions were likely to be achieved, e.g., propulsion systems, structures, aerodynamics or systems improvements. They also indicated the kinds of technologies that would need to be developed in these areas for both noise and emissions. The general tenor of the NASA analysis was that achieving the Goals would be very challenging, but that with adequate resources, the Goals were achievable.

Following the presentations and discussions of the roadmaps, NASA posed four questions for the participants to answer. The participants were organized into three groups. Each of the groups was composed of individuals associated with organizations that were believed to have similar concerns and interests. The Groups included one for operators, both airline and airport operators; another for the aircraft and engine manufacturing industry; and the third group for non-governmental organizations (NGO's), environmental organization representatives, state and local government, and community representatives. Federal agency employees attending the meetings were free to observe any of these Breakout Groups. Each of the Groups met separately and was asked to address the same four questions dealing with the Environmental Goals, Research Strategy, Roadmaps, and Moving Forward. The questions and highlights from the responses are provided below.

1. Will the attainment of the goals satisfy **your** environmental concerns?

The answers to this question varied from a qualified yes to a qualified no. Key points included:

- The environmental goals of the Three Pillar's are technology goals while the environmental concerns were the levels of emissions and noise from the fleet of operating aircraft,
- Other criteria (safety, affordability, etc.) must be part of any solution before the technologies can be seriously considered for implementation.

- There were several comments about the content and meaning of the goals e.g., the emission goals needed to be clarified; more near term goals were needed; relationship to other types of aircraft was not clear; and the goals may not be adequate to address the CO_2 issue.
- Development of improved measures of perceived and actual impacts of noise and emissions on humans is essential.

2. Does the NASA strategy appear to be appropriate?

The responses generally indicated that the strategy was appropriate and flowed from the gap analysis, however, all three groups took the opportunity to provide additional comments some of which are provided below.

- The strategy needed to extend beyond research and technology; that is, concurrent strategies addressing market acceptance, certification, regulation, operations and other problems were necessary to achieve overall success.
- Funding needed to be available for development of promising technologies through Technology Readiness Level 6,
- Coordination between NASA research activities and that of other agencies, such as the Departments of Defense, Energy and Transportation and particularly with the Federal Aviation Administration, needed to be strengthened, and
- Broad advocacy is essential.

3. Have the roadmaps reached appropriate near and far-term balances? Leveraged other government and industry programs? Identified technologies to be pursued ASAP?

The groups felt that it was important to strike a balance between near and far-term programs with the near-term focusing on aircraft and engines that utilize hydrocarbon fuels.

- Short and intermediate term solutions are needed, improved aircraft and engine efficiency and better atmospheric and noise models were given special mention,
- Continuing systems studies are important to evaluate the benefits of proposed activities including revolutionary concepts and the interaction of goals.
- While technology is being developed, operational improvements (e.g., CNS/ATM), use of AST program technology development, and other measures (retrofits using available technology) need to be employed,
- 30 to 40 year goals for zero emission aircraft are important, but it should not be a tradeoff for near term goals,
- Alternative carbon based fuels were not viewed as being attractive, the opinion was that they had all the problems associated with building a new fuel infrastructure and few benefits, and
- Finally the role of NASA in far term research and technology development was viewed as crucial…"NASA has a critical role to play in a basic R & D program and in 'thinking outside the box!' "

4. What form of continuing communication with NASA would be of value? In what way would you be willing to participate in pursuit of these research objectives?

All of the Groups expressed the view that continuing communication with NASA would be of value to their organizations and constituents and expressed a willingness to be actively involved in such an effort. Among the steps proposed for continuing communications were the following:

- Creation of a technical steering committee modeled after the AST Noise Reduction Steering Group.
- Expanding participation in meetings and workshops on environmental issues to include other relevant groups.

- Six-month reports on the progress of the research programs along with research test results and technical points of contact.
- Reports or articles understandable to the layman that can reach the broader community concerned about these issues.
- Continuation of the NASA ECoA website with expanded information and links to other relevant sites.

In response to the second part of the question, the Groups indicated their willingness to participate in the following ways:

- Manufacturers indicated that they would like to be involved in technology development efforts that will be part of the NASA program so that they will be better prepared to implement resulting technologies in future products.
- Providing forums for the discussion of the issues and the research activities at conventions, technical symposia and association meetings dealing with environmental issues.
- Use of airport facilities as test beds for development programs.
- Providing their time and expertise to review program proposals and provide NASA with an awareness of the concerns of their constituents.
- Assisting in public communication and education of decision-makers.

Participant Insights:

A number of interesting insights surfaced in the responses of the workshop participants. First, despite the differing interests of these Groups, their views and opinions were remarkably consistent regarding the Goals and the overall research and technology development activities. One such view was the opinion of all three Groups that more needed to be done in the near future. This reflected their feelings that the problem was more urgent than may have been generally assumed and that new technology would take substantial time to implement before it would have a significant impact on the commercial fleet of aircraft.

All three Groups emphasized the need for improved efficiency as a means of addressing emissions and noise problems. This improved efficiency relates to a broad range of possible improvements to airframes and engines, as well as system and operational improvements. This was believed to be of particular importance in addressing problems of both local air quality and global climate change.

All three Groups recommended that efforts be made to improve the level of scientific knowledge of aircraft noise and emissions and their effects on the environment and to develop better models and metrics. These tools are important in understanding the impacts related to local air quality, noise, and atmospheric chemistry at high altitudes.

Finally, all three Groups strongly supported continuing the communication that had been started through the workshop series. They expressed a willingness to participate in such a dialogue and to contribute their energy, time and expertise to such an undertaking.

In terms of a bottom line, the workshop participants expressed general support for the NASA ECoA Program. Despite different interests, the workshop participants recognized the importance of developing technology options that can address the environmental impacts of aviation. All indicated a willingness to be involved in this effort and to provide their views and opinions regarding the focus and direction of the NASA Environmental Compatibility Program.

Conclusion:

The methodology selected by the NASA ECoA Core Team to implement their charter included a series of three workshops with participation by the interested segments of the aviation and environmental communities. In selecting this "modus operandi", the Core Team opened the NASA door to the suggestions, criticisms and recommendations of not only its customers, but also, in some cases, to its critics. The intent was to achieve consensus on NASA's approach, plans, and programs to reduce emissions and noise from aviation.

The workshop attendees actively participated and contributed to the products of the workshop. They reviewed and critiqued proposed technologies, questioned assumptions, and challenged the proposals presented by NASA as well as those of their fellow participants. In addition to their comments and opinions, they also gave presentations and shared information.

In terms of redefining the issues, the workshop participants expanded the concept of program success beyond the development of technology to include its application and use. They urged NASA to include market acceptance, safety, economics, certification, and other important facets of deployment as key elements of their strategic plans.

The participants encouraged NASA to take the lead in coordinating the research of other federal agencies that had potential applicability to commercial aviation.

In yet another demonstration of their broader perspective, the participants emphasized the importance of taking a more systematic look at problems and potential solutions, carefully weighing both the direct and indirect costs and benefits. A good example of this was the suggestion that before undertaking a major research effort on alternative hydrocarbon fuels, the cost of the additional infrastructure that would be required and the benefits that would accrue needed to be systematically weighed.

While encouraging NASA to strike a balance between near and long-term research, the participants emphasized the importance of considering "the low hanging fruit" to achieve near term successes. The participants emphasized the importance of improved fuel efficiency and improvements in operations as two areas with significant potential for near-term payoff.

It seems reasonable to conclude that the participants reached many significant points of consensus regarding the scope and direction of the NASA Environmental Compatibility Program. In weighing these examples of consensus, broadening the perception of the problem and the definition of success beyond research and technology development to "the bottom line" was perhaps the most important contribution of the workshops.

The Chairman's Perspective:

The ECoA workshops were a successful first step toward the goal of reducing the environmental impacts of aviation in the years ahead. As a first step the workshops scored some impressive successes. The participants were active and involved in the discussions and brainstorming sessions. They overwhelmingly stated that these meetings had been useful and some form of communication, dialogue and information exchange should be continued. In short, the groundwork has been established for an effective working relationship between NASA and the community of interests that look hopefully to NASA's research endeavors.

Improved relationships and lines-of-communication with these constituencies are important to the success of NASA's environmental program. They are particularly relevant if NASA is to improve the effectiveness of the transfer of environmental technologies into solutions capable of implementation.

There is also the hope that these groups could become advocates for the Environmental Compatibility Assessment Program and provide support in the budgetary process.

If these objectives are to be attained, then the lines of communication established in the workshops must not only be maintained, but must be strengthened. Furthermore, program advocates will surface when concerned constituents become aware of the details of the program and the decision processes under which it operates. When they recognize that their interests and needs and those of the program are compatible; when they perceive that they are informed and listened to; and when they recognize that their long term interests are well served by the program; then they will actively support NASA in this endeavor. At this time, the participants support the Goals and the concept of the program, but lacking knowledge of the program specifics, they are hesitant to go beyond that amorphous level of support.

Thus the NASA workshops have created a set of expectations on the part of the participants. They expect to be informed in a timely fashion and they hope that their opinions, assessments and, most particularly, their concerns will be heard and acted upon. This is the challenge that needs to be addressed as more detailed information on the specific research projects becomes available. To accomplish the technology transfer and advocacy goals that were set at the beginning of this undertaking, NASA must now create the vehicle to continue the effective two-way dialogue. This is the challenge that NASA must face if it is to maintain the momentum generated by that first step.

Environmental Compatibility
Workshop I
Summary Report

The NASA Environmental Compatibility Assessment Workshop met in Atlanta, Georgia on March 17-19, 1998 for the purpose of addressing the environmental issues facing aviation. Concern about the environmental impact of aviation has arisen as a result of the growth of aviation and the expectation of continued growth in the foreseeable future. To address these issues NASA initiated a series of workshops to assess the contribution that new technology might have on mitigating or lessening the future environmental impacts. Approximately 85 participants attended the Atlanta workshop. They were affiliated with various segments of the aviation industry, the environmental community, academia, federal government agencies and other interested parties.

The workshop opened with several presentations and panel discussions that set the stage for the group deliberations and helped to define and bound the problems of interest. Following the opening session the participants divided into Breakout Groups that discussed the key Technical and Framework issues associated with aircraft Noise and Emissions. To initiate the workshop discussions four questions were presented to the participants:

1) What are the impacts of aviation noise and emissions on the environment?
2) How do you believe these may affect the growth of aviation?
3) Must the growth of aviation lead to increased environmental impacts?
4) What is the relationship of the NASA noise and emissions goals to aviation's impact on the environment?

While these questions were used to stimulate the discussions, they were not intended to be answered as the first order of business of the workshop. They served as signposts to indicate the general focus of the workshop efforts. At the concluding session of the Workshop the Breakout Group leaders reported on their findings and conclusions at a Plenary Session. These are summarized in the sections below.

Noise Breakout Group:

The Noise Breakout Group provided a list of major issues that needed to be addressed; these included—1) A clear definition of the noise goals (as presented in the NASA Administrator's "Three Pillars" plan; 2) Metrics to provide targets and measure performance; 3) Certification and Regulation; 4) Strategies to achieve the goals; 5) Implementation Issues, and 6) Costs and Benefits. Metrics was an important issue for the group. It highlighted the disconnect between technical measurement associated with technology development and performance from the perspective of the scientist and engineer as opposed to noise levels deemed acceptable to the public that may be influenced by variables, such as weather conditions, time of day, cumulative noise effects and personal sensitivities. In addition, assumptions regarding an appropriate set of metrics are essential for establishing a clear definition of the "Three Pillars Goals" as well as Certification and Regulation criteria and the establishment of technology development targets.

The Noise Breakout Group identified a number of strategies to reduce of aircraft noise levels and achieve public acceptance. These included a number of different approaches, such as research and development in unconventional airframes and engines, noise as an airframe design parameter, source noise reduction, and fixed and adaptable designs. They also called for a balance between Base and Focus programs and attention to low frequency noise and vibration problems. The Group also identified a number of areas where systems approaches and operational changes might lead to noise reductions (ATM to include noise considerations, flight operations, and taxi and ground procedures). In addition the Group acknowledged

that while there were some similarities, the problems of helicopter noise were different in many respects (quality, frequency, and flight paths) from that of standard fixed wing aircraft.

In discussing implementation Issues for NASA technologies, the Group identified a number of issue areas, such as the retrofitability of solutions, time from research to implementation, aircraft and engine integration, trade-off between noise and other performance criteria, and the ability to develop noise reduction technologies capable of being produced.

The Noise Breakout Group also identified a number of broad "overarching" issues. These included the observation that trends in population growth and aviation growth had the potential to exacerbate the noise problem. The questions of who should pay for reducing noise levels and how should that be accomplished were raised? There was some discussion on the role of public education, the methods of public response, and a better understanding of public acceptance and how it should be determined or measured. The opinion of the Group was that some research into the "soft areas surrounding the public and the effects of noise" was important.

In concluding its presentation the Noise Breakout Group identified those areas which they believed were important to concentrate on at the Second Workshop. These included--1) Step Changes versus Paradigm Shifts; 2) Technologies to achieve the NASA goals; 3) Technology Barriers, and 4) Benefits and Risks. Finally, the Group asked that information from a study of noise levels at selected airports be presented at the next workshop.

Emissions Breakout Group:

After some initial discussion of the questions presented to the workshop, the Emissions Breakout Group turned its attention to the development of a structure to organize its discussions. Three major classes of problems were identified (Ozone Depletion, Global Climate Change, and Local Air Quality). For each of these classes of problems they identified the emissions of greatest concern (such as, nitrogen oxides (NOx), Carbon dioxide (CO2), and other gasses or particulate of concern). Using this structure the Emissions Group then posed five basic questions for discussion—1) What should the high level NASA Program Objectives be? 2) What should the NASA Program focus be? 3) What should the scope, magnitude, and timing of emission reductions be? 4) What are the key technology issues? 5) What are the overarching issues and questions? The material below provides an overview of some of the recommendations of the Emissions Breakout Group.

NASA Program Objectives—Should provide technology so that aircraft do not have a significant impact on the ozone layer; develop technology to contribute to improvements in local air quality; and develop technology that ensures aircraft are compatible with Global Climate Change goals.

NASA Program Focus—Should protect the Ozone layer by focussing on NOx and Sulfur/Aerosols and performing basic research on ozone chemistry and transport and atmospheric models; should emphasize reductions of emissions (particularly in the landing and takeoff cycle (LTO)) of NOx, Volatile organic compounds (VOCs), and Carbon monoxide (CO) to improve local air quality; should reduce fossil fuel burned (as much as possible as soon as possible and feasible) and should look beyond fossil fuels to address Global Climate Change.

Scope, Magnitude, Timing of Reduction—By 2030 return ozone to pre-CFC (Chloro-fluoro-carbon) state; reduce NOx by 35 percent by 2003 to improve local air quality; and reduce fossil fuel burned (as much as possible and as soon as possible) to minimize global climate change.

Key Technology Issues—For ozone protection, minimize cruise NOx and focus on better science and models; for local air quality, minimize NOx and VOCs in LTO cycle; and for Climate Change, identify the limits for conventional hydrocarbon fuels (practicable and feasible).

Overarching Issues—examine trade-off among emittants; develop system-level design tools; work on longer term solutions/technologies beyond fossil fuels; pay attention to affordability and economic feasibility; need for compatibility between new technologies and procedures with noise requirements. Finally, the group put forth the opinion that they "do not want to limit aviation growth IF we can address environmental issues.

In preparation for the Second Workshop the Emissions Breakout Group asked that a number of studies and reports be provided. In addition, they asked that NASA provide some assessments of performance of the current fleet; LTO cycle emissions; change achievable for state-of-the-art low NOx combustors; emissions distribution model (to look at large levels), and a maximum achievable system study.

Details from the Breakout Group Presentations are contained in the minutes of the First Workshop on the NASA Environmental Website.

NASA ENVIRONMENTAL COMPATIBILITY RESEARCH WORKSHOP I
Atlanta, GA
March 17-19, 1998

Agenda

Tuesday, March 17, 1998

7:30 a.m.	Continental Breakfast	
8:00 a.m.	Welcome and Introductions	Howard Wesoky
	Workshop Process	Frank Murray
9:00 a.m.	Keynote Speakers/Panel Discussions/Presentations	
	Keynote Speaker	Steve Moran (OSTP)
	Aviation and the Environment: Public Interest Perspective Panel	Carolyn Cunningham (NRDC) Sue Gander (CCAP) Annie Petsonk (EDF) Betty Kane (N.O.I.S.E.)
10:30 a.m.	Mid-morning Break	
10:45 a.m.	Aviation and the Environment: An Industry Perspective Panel	Howard Aylesworth, AIA John Leverton (GKN Westland) Ray Brown (Delta Air Lines) Belur Shivashankara (Boeing) Steve Morford (Pratt & Whitney)
	Aviation and the Environment: An Airport Operator Perspective:	Dick Linn (DFW) Ben Sharpe (Wyle) Carrol Bryant (Transportation Solutions)
1:00 p.m.	Lunch (provided)	
2:00 p.m.	Open Discussion Working Group Process	
3:30 p.m.	Mid-Afternoon Break	
	Establish Working Groups	
	Framework Working Group: What are the Environmental issues that are likely to impose fundamental limitations on aviation's growth?	Chairperson – Annie Petsonk Facilitator – Michael Loescher

	Technology Working Group: What are the technical challenges faced in eliminating the fundamental limitations to aviation's growth?	Chairpersons – Krish Ahuja and Ian Waitz Facilitator – Deborah Peisen
5:00 p.m.	Adjourn	

Wednesday, March 18, 1998

7:30 a.m.	Continental Breakfast	
8:00 a.m.	Reconvene Plenary Framework Working Group Feedback Technology Working Group Feedback	
12:00 p.m.	Lunch (provided)	
1:00 p.m.	Reconvene Working Groups Address Plenary Comments Determine Required Information Prepare Report for Thursday Morning Presentation Define Actions for SAIC, NASA, and Working Groups	
5:00 p.m.	Adjourn	

Thursday, March 19, 1998

7:30 a.m.	Continental Breakfast	
8:00 a.m.	Reconvene Plenary for Working Group Reports Framework Report Technology Report	
11:00 a.m.	Rapporteurs "impressions"	Cindy Newberg, Don Sutkus
11:30 a.m.	The Way Forward Review of actions for SAIC, NASA, and Working Groups Discussion of agenda for following workshops	Frank Murray, Howard Wesoky
12:00 p.m.	Adjourn	

For updated information on attendance, agendas, meeting notes, etc., please refer to the NASA Environmental Research Compatibility Workshop Website at:

http://www.hq.nasa.gov/office/aero/oastthp/programs/encompat/encompat.htm

MINUTES OF THE NASA ENVIRONMENTAL COMPATIBILITY RESEARCH WORKSHOP
HELD MARCH 17 - 19, 1998
AT THE RADISSON HOTEL, ATLANTA, GEORGIA

The following persons attended this Workshop.

First Name	Last Name	Company
Krish	Ahuja	Georgia Institute of Technology
Richard	Antcliff	NASA Langley
Howard	Aylesworth	Aerospace Industries Association of America
James	Baeder	University of Maryland
David	Ballard	GRA, Inc.
Peter	Batterton	NASA Lewis
Steve	Bradford	FAA
Gerald	Brines	Allison Engine Company
Raymond	Brown	Delta Airlines
Carrol	Bryant	Transportation Solutions, Inc
Adina	Cherry	SAIC
Kestutis	Civinskas	NASA Lewis
John-Paul	Clarke	Massachusetts Institute of Technology
Thomas	Connor	FAA
Carolyn	Cunningham	Natural Resources Defense Council
Robert	Cuthbertson	The Boeing Company
Walter	Desrosier	GAMA
William	Dodds	GE Aircraft Engines
John	Dodge	AlliedSignal
Douglas	Dwoyer	NASA Langley
James	Erickson	FAA
Sue	Gander	Center for Clean Air Policy
Phillip	Gliebe	GE Aircraft Engines
Richard	Golaszewski	GRA, Inc.
Mark	Guynn	NASA Langley
Dennis	Huff	NASA Lewis
Tina	Hunter	FAA
Rodney	Jago	SAIC
Betty Ann	Kane	N.O.I.S.E.
Richard	Lawrence	NASA Goddard
Cindy	Lee	NASA Langley
John	Leverton	GKN Westland
Diana	Liang	FAA
Dick	Linn	DFW Airport
James	Littleton	FAA
Michael	Loescher	SAIC Consultant
Wesley	Lord	Pratt & Whitney
Stephen	Lukachko	Massachusetts Institute of Technology
Gary	Machles	GE Aircraft Engines
Ty	Marien	NASA Langley
William	Marx	FAA

Douglas	Matthews	Pratt & Whitney
Edward	McQueen	FAA
Richard	Miake-Lye	Aerodyne Research Inc.
Nicholas	Miller	Harris, Miller, Miller & Hanson
John	Mitchem	Allied Signal Aerospace
Steve	Moran	White House/OSTP
Stephen	Morford	Pratt & Whitney
Frank	Murray	SAIC Consultant
Cindy	Newberg	EPA
Robert	Pearce	NASA HQ
Deborah	Peisen	SAIC
Annie	Petsonk	Environmental Defense Fund
Clemmons	Powell	NASA Langley
Ronald	Ray	NASA Dryden
N.N.	Reddy	Lockheed Martin
Lisa	Reuss	SAIC
Karen	Robertson	DFW Airport
John	Rohde	NASA Lewis
Carol	Russo	NASA Lewis
Ben	Sharp	Wyle Laboratories
Nancy	Shelton	FAA
Belur	Shivashankara	The Boeing Company
Jim	Skalecky	FAA
Glenn	Smith	NASA HQ
Chuck	Smith	NASA Ames
Paul	Soderman	NASA Ames
David	Stephens	NASA Langley
Gary	Stowell	San Jose International Airport
Donald	Sutkus	The Boeing Company
Richard	Thompson	HMMH
Ian	Waitz	Massachusetts Institute of Technology
Donald	Weir	AlliedSignal
Howard	Wesoky	NASA HQ
Michael	White	Mitre Corporation
William	Willshire	NASA Langley

The following represents a synopsis of the discussion at this Workshop as related to the published agenda.

I. Welcome and Introductions

Mr. Howard Wesoky opened the workshop by welcoming attendees and then presenting the following remarks:

> Thanks for participating in this workshop. I greatly appreciate that you are spending valuable time and financial resources here, but believe the workshop can be valuable to you and your organizations, as well as to NASA.

It is good to see so many old friends and to hopefully have an opportunity to make some new ones. Because the NASA organization seems to change daily, let me introduce myself to everybody. I am currently Team Leader for Environmental Compatibility Assessment in the NASA Headquarters Office of Aeronautics & Space Transportation Technology in Washington, DC. And although my training and most of my professional experience has been in aeronautical engineering, I have spent much of the last nine years overseeing NASA's studies of the atmospheric effects of aviation, primarily a scientific endeavor. That has helped me to begin understanding global climate change and stratospheric ozone depletion issues. Participation in studies of aircraft noise and emissions technology has also provided some knowledge of local environmental concerns as well. But I hope to have a much better understanding of all of the related issues by noon on Thursday.

Because of the great romance with space exploration, some of you may have been surprised to learn that NASA is involved in aeronautical research. The National Advisory Committee for Aeronautics was founded in 1915, just twelve years after the Wright Brothers first flight. In 1958, NACA charter was folded into the Space Act, which was the authorizing legislation for the National Aeronautics & Space Administration. The particularly relevant directive is that NASA is to maintain a leadership position for the United States in aeronautical science and technology.

NASA researchers have also been active in ensuring that aeronautical technology is friendly to the environment. For example, the Pratt & Whitney engines, which make the Boeing MD-80 one of the most quiet airplanes, use technology developed in NASA sponsored programs. And the GE engines, which use the newest low emissions combustors, have also benefited from NASA investments. My NASA colleagues can relate many other examples of how your tax dollars are helping airplanes to be clean and quiet.

But 'clean and quiet' are relative terms, and you may not agree that airplanes are friendly enough to the environment. Even more likely, we all might agree that the phenomenal growth of the aviation industry might threaten its environmental compatibility. The White House Office of Science & Technology Policy expressed concern about this matter in 1995 when it reported that "Environmental issues are likely to impose the fundamental limitation on air transportation in the 21st century." Because of this concern, OSTP has recommended that a key national goal be to "Ensure the long-term environmental compatibility of the aviation system." I am sure that our keynote speaker this morning will have more to say in that regard.

NASA Administrator Dan Goldin picked up on this theme in his 1997 response, "Aeronautical & Space Transportation Technology: Three Pillars for Success." Speaking for NASA, he suggested that "there are technological solutions that will significantly reduce aircraft emissions that contribute to global warming and ozone depletion, even as travel volume increases." Mr. Goldin also asked if "we [can] go further and create aircraft that are so quiet that the predominant noise at airports comes from cars and buses?"

To move in this direction, the NASA Aeronautics Enterprise collaborated particularly with the aeronautical manufacturing industry to develop "stretch goals" for both emissions and noise under the 'Global Civil Aviation Pillar.' These goals are meant to enable the aviation industry to:

- Reduce emissions of future aircraft by a factor of three within 10 years, and by a factor of five within 20 years, and

- Reduce the perceived noise levels of future aircraft by a factor of two from today's subsonic aircraft within 10 years, and by a factor of four within 20 years.

And as stated in the *Three Pillars* brochure, which most of you have seen by now, both of these environmental goals have the requirement to be achieved without affecting safety or affordability.

Since the first statement of these goals about a year ago, there have been many questions about their meaning. For example, exactly what emissions are to be reduced at the 10 and 20-year horizons? And exactly what is to be the state of technology development or application at these horizons? I am sure that you have other questions about these or the other goals associated with the *Three Pillars.*

The most basic response to these questions is that the goals were originally articulated in a purposely dramatic although somewhat ambiguous manner for Administrator Goldin's overarching message, while allowing later development of appropriately more clear definitions for each of the specific enabling technology areas. And after using their collected wisdom to stretch our imaginations, the executives responsible for the Three Pillars then assigned NASA teams to assess the ability of current programs to achieve the various goals and to determine what additional effort may be required (i.e., "gap" analyses).

Members of the NASA Environmental Compatibility Assessment (ECoA) Core Team are:

- NASA Headquarters: Howard Wesoky
- Dryden Flight Research Center: Ron Ray
- Ames Research Center: Chuck Smith, Paul Soderman
- Langley Research Center: Doug Dwoyer, Dave Stephens
- Lewis Research Center: Carol Russo, John Rohde

So we are the NASA employees who are most concerned with your views. Each of us is identified by their badge, and only Carol Russo is not here today. She will join us tomorrow.

In collaboration with carriers, manufacturers, academia and other government agencies, NASA will develop robust technology options with the objective that environmental issues do not constrain the growth of air transportation.

Recognizing the importance of eliminating some of the ambiguity of the goals, we have similarly begun to draft answers to some of the glaring questions previously mentioned. For example, the emissions goal specifically refers to oxides of nitrogen (NOx), but there are parallel CO_2 considerations in the present NASA programs, which will be the principal source of technology at the 10-year horizon. We are currently evaluating what levels of CO_2 reduction are appropriate for both the 10 and 20-year horizons.

Based on our understanding of technology transfer, we also believe it is plausible for the benefits of NASA programs to begin appearing in the marketplace at these horizons. Although please recognize this does not necessarily mean that NASA technology should immediately serve as regulatory standards at those horizons.

Those of you who do not fit in the categories specified as co-developers of technology options should not feel left out at this point. For the purpose of this workshop is to seek information from those who are subjected to aircraft noise and emissions, as well as those responsible for related research and technology. The ECoA Core Team would like all of us to address this basic set of questions at this and the following workshops:

- What are the impacts of aviation noise and emissions on the environment?
- How do you believe those impacts may affect the growth of aviation?
- Must the growth of aviation lead to increased environmental impact?
- What is the relationship of NASA's noise and emissions goals to aviation's impact on the environment?

Once we have heard your responses to these questions, the ECoA Core Team believes that we will be much better prepared to suggest the technology options that may be necessary to avoid environmental constraints to aviation's growth.

So for the remainder of the workshop, the Core Team would like to primarily listen to you. Therefore, to avoid having NASA monopolize the agenda and discussion, we have asked SAIC to manage the workshop and for Francis X. Murray to be our chairperson.

Frank is currently Senior Advisor and Director of the Interstate Cooperative Initiative Program to the Global Environment and Technology Foundation. You can ask him for information about the foundation. I am impressed that it was the recipient of The Vice President's National Performance Review Award.

Frank has more than 25 years of experience in government, business, non-profit institutions and academia. This includes serving as Staff Director from 1989-95 for the Subcommittee on Energy of the U.S. House of Representatives Committee on Science. He has been a member of the Adjunct Faculty at the Georgetown University's School of Foreign Service for over 20 years where he has taught a Graduate and Honors Seminar in International Energy and Environmental Issues.

He is especially well prepared to participate in our workshop having served from 1974-82 as Director of the National Coal Policy Project, a pioneering effort in environmental dispute resolution that brought together industry and environmental leaders to seek consensus on the policies for using coal in an environmentally and economically acceptable manner.

Frank is now going to explain what we will be doing for the next 2 1/2 days, and I am looking forward to what he has planned for us!

Frank Murray reiterated Howard's welcome to the participants and stated that the number of interested parties attending the workshop encouraged him. He also stated that the different backgrounds, interests, and beliefs prevalent in the audience provided a wonderful opportunity to work together and achieve results which will not only help NASA choose a path for future research but also provide meaningful input on the environmental issues of emissions and noise. He noted, "Too often we view economic growth and environmental health as being mutually exclusive goals. As a society we need to find ways to accommodate both. Technology can play a key role in finding the pathways that will allow us to grow and have a healthy environment." He concluded that all of us present today have a stake in finding answers to the environmental problems facing aviation. The workshop goal is to tap our collective experience and knowledge to provide insights into how aviation can continue to grow without having an adverse impact on the environment. Finding such solutions is important to all of us, and your active participation in this effort can provide a positive impact on the environmental issues as they relate to the continued growth of aviation.

II. Workshop Process

Following these remarks, Frank then briefly reviewed the Workshop Agenda and process, stating that the panel and speaker presentations would follow after the Keynote Speaker's presentation. He stated that following these presentations and an open discussion, working groups would be established and meet to formulate their plans of action. Further discussion on working group responsibilities would take place later in the workshop.

III. Keynote Speakers/Panel discussions/Presentations

Copies of the materials used by the speakers in their presentations are available on Environmental Compatibility Website at: http://www.hq.nasa.gov/office/aero/oastthp/programs/encompat/encompat.htm. Following is a summarization of the presentations.

A. Keynote Speaker: Steve Moran, OSTP

The Keynote speaker for the Workshop was Steve Moran from the Office of Science and Technology Policy in the White House. In terms of background, he was involved in aviation technology and policy at both the national and international level throughout his professional career. His remarks provided the context within which the issues of aviation and environment will be addressed.

Topics discussed by Steve included the Administration's policy on aeronautical research and development, the United Nations framework convention on climate changed, and the Administration's policy on climate change. The Administration's goals are to maintain superiority of US aircraft and engines while improving safety, efficiency and cost effectiveness. At the same time, the goals include ensuring long-term environmental compatibility of the aviation systems. Steve also reviewed the US policies and 3-stage action plan to achieve these goals. The Kyoto protocol was discussed, as were NASA's goals with respect to environmental compatibility.

B. Aviation and the environment: A public interest perspective

Frank introduced the first panel of speakers that presented the views of several public interest groups regarding the environmental impacts of aviation. This panel included Carolyn Cunningham from the Natural Resources Defense Fund; Carolyn also served as the chairperson for this panel. Carolyn's presentation was developed primarily from the contents of NRDC's Executive Summary of their report, Flying off Course. The Executive Summary is available through the NRDC website. (http://www.nrdc.org/nrdcpro/foc/aairexsu.html)

Following Carolyn, Sue Gander from the Center on Clean Air Policy (CCAP) discussed the concerns regarding the emissions of aircraft in light of the recent growth of all types of aviation and the forecasts for continued growth in the future. Of specific concern are the health impacts and the fact that approximately 70 million people live in areas that exceed current ozone standards. The ozone problem poses major challenges to state and local officials. It is recognized that aviation is a small contributor, but the problem will increase in proportion to the growth of aviation.

Annie Petsonk of the Environmental Defense Fund followed and covered a number of environmental areas. In particular she discussed the Kyoto Conference on Climate Change and the current uncertainty as to how this would be translated to the Aviation Industry. The need to resolve issues such as national emissions goals and the treatment of international flights was raised. She also noted the wide interest in using market mechanisms as a means of banking and trading emission reductions to meet the Kyoto Goals.

Completing the Public Interest Panel Betty Anne Kane of the National Organization to Insure a Sound Environment (NOISE) discussed the problems associated with noise around airports as traffic volume increases and airports expand the number of runways to accommodate this traffic. She noted that while some progress has been made, there is still a need for further progress. Additional research is needed in both the noise and emission areas. Human responses to noise needs to be investigated to determine whether noise causes detrimental effects other than sleep loss. Research on insulation and noise barriers also needs to be conducted. Short Takeoff and Landing (STOL), quieter engines, and steep angled approaches are other areas requiring additional research.

C. Aviation and the Environment: An Industry perspective.

The second panel was composed of members from the aviation community. Howard Aylesworth, of the Aerospace Industries Association chaired this panel. Howard's remarks noted the advances that the industry had made over the past several decades to improve their performance vis-à-vis the environment. He noted that it takes considerable investment in time and resources to introduce basic changes to aircraft designs or engines. These requirements mean that the industry cannot instantly respond to new environmental concerns. He also noted that aviation is the most highly regulated industry in the world.

Following those remarks, John Leverton, a helicopter consultant, discussed the peculiar problems of helicopters especially in relation to concerns about noise. He mentioned that virtual noise is much worse than real noise in regard to rotorcraft. John stated that additional research is needed on rotorcraft noise abatement procedures, that current procedures force helicopters into a noise flight mode.

Ray Brown, of Delta Airlines, discussed the airline operator's perspective and their efforts to keep their fleet of airplanes abreast of the latest improvements in terms of environmental performance in a highly competitive industry. He noted that Delta and other airlines have implemented fuel conservation methods and consequently, fuel efficiency is steadily improving. Since fuel is Delta's second highest expense, reduced fuel usage is a continuing goal. Achieving this goal will also result in lower aircraft emissions. It was also noted that the implementation of a new CNS/ATM system would help in both respects.

Belur Shivashankara from Boeing discussed the various airframe design and engine parameters that affect the noise levels of aircraft during various stages of the airplane operations, as well as the environmental performance of newer aircraft entering into service. He noted that there are 3 major issues associated with aircraft noise: engine and airframe noise reduction; operating procedures; and land use planning. He pointed out that technology implementation is costly and takes time; that breakthrough technologies are needed to implement cost effective noise solutions; and that noise exposure to service personnel and the crew are emerging issues. He concluded that a balanced approach is needed to achieve desired results.

Finally, Steve Morford, of Pratt and Whitney, covered aircraft engine performance and the requirements for safety and for formal certification of new engine types. He mentioned that the issue is not engine technology but rather implementation and economics.

D. Aviation and the environment: An airport operator perspective:

The final discussion panel was composed of Dick Linn from the Dallas Fort Worth Airport and Ben Sharpe of Wyle Laboratories. (Carrol Bryant of Transportation Solutions, who was scheduled to make a presentation at this time, was unable to attend.) Dick Linn spoke extemporaneously in regard to an airport operator's perspective of environmental issues with particular emphasis on the noise issue, giving an account of the practical problems in trying to address the complaints about noise. He related that his involvement first began when he was employed by American Airlines as an Aeronautical Engineer for 30 years. Noise impacts first began to be an issue with the fielding of the 727. NASA's involvement began

in the early 60's and progress on noise reduction particularly related to engines began to take effect. As noise levels decreased with the advent of the new, quieter engines however, people began to chase the reducing contour lines and new housing developments were being built closer to airports.

NASA's Advanced Subsonic Transport (AST) program should result in maybe a 10dB reduction in noise, but the fear is that additional chasing of the contour line will occur. If a reduction to 55 DNL[1] is required, the airlines should not have to endure this extremely expensive requirement. Costs should be shared. Where airports have expanded and impacted local populace, mitigation programs have been implemented and financed by airport authorities.

Dick went on to cite specific examples of how airports were being impacted by the environmental concerns about noise. He also spoke briefly about airport localized emission problems. The overall message of Dick's presentation was that industry to this point has financed this entire effort and now it was time for the communities to help support this effort.

Dick is preparing a paper to express his thoughts on the subject, and it will be ready for dissemination in about thirty days, well before the Cleveland Meeting.

Ben followed with a discussion of a study that is being undertaken by his organization. He emphasized the number of variables that are at play in correlating measurable noise levels with subjective opinions as to acceptable and unacceptable noise levels.

Since most of the discussion occurred following the panel presentations, very little discussion took place during this Agenda Item.

V. Working Group Process

The Chairman, Frank Murray, opened this Agenda Item by referring to the Working Group Matrix provided as a handout. He explained that the Framework and the Technology Groups would meet in separate rooms and begin to formulate plans of action for their individual areas of responsibilities. He stressed that as a "rule of engagement" participants should not assume what others would say, but rather listen and try to understand what was meant and to ask questions if understanding was lacking. He encouraged everyone to pursue this effort with an open mind with the intent of providing meaningful inputs that can have a positive effect on the overall outcome. Following these words, the two Groups separated into their separate sessions.

VI. Establish Working Groups

A. Framework: What are the environmental issues that are likely to impose fundamental limitations on aviation's growth?
   Chairperson Annie Petsonk and Facilitator Michael Loescher led the efforts of the Framework Group.

B. Technology: What are the technical challenges faced in eliminating the fundamental limitations to aviation's growth?

[1] DNL: Day-Night Level. The calculated energy averaged A-weighted sound level (measured in decibels) over a 24-hour period with a 10-decibel adjustment added to the sound levels between 2200 and 0700. This time weighting is applied in an effort to account for assumed increased sensitivity to noise intrusions during the nighttime hours.

After a very brief discussion, it was decided that the Technology group should be further broken down into Noise and Emissions subgroups. Krish Ahuja was designated chairperson for the Noise Subgroup and Ian Waitz led the Emissions Subgroup.

In the Noise Subgroup, Krish used the brainstorming technique to identify issues that could impact the achievement of future aviation growth. During this session over 60 issues were identified. These issues were used for the preliminary subgroup report during the next day's session.

In the Emissions Subgroup, Ian also used the brainstorming technique to identify issues. These issues were broken into 3 groups: (F) need framework input; (T) pure technology; and (N) noise/emission discussion. These issues were used for the preliminary subgroup report during the next day's session.

VII. Reconvene plenary

During the opening session of the workshop's second day, the leaders of the respective breakout groups reported to the plenary the general tenor of their discussions and the direction that was proposed for the coming sessions. They also noted any problems or issues that their particular breakout group encountered. Where appropriate they asked for comments or redirection from the plenary group.

A. Framework Working Group feedback

The framework group had difficulty getting focused on its task. The use of the term framework was a source of some confusion; because of this confusion, technology issues kept creeping back into the group discussions. There was also a tendency to move back and forth between examples in the noise area and examples in the emissions area. This added to the difficulty of keeping the group focussed on the task at hand. The Framework breakout group had only a few conclusions to put on the table at this session. Because broad framework issues are by definition less specific and more nebulous, the group struggled to get started. They did agree that aviation growth should not be limited if it could be accomplished without an increased impact on the environment.

B. Technology Working Group feedback.

Krish and Ian reviewed the progress of their individual subgroups from the previous afternoon's session. Essentially, Krish briefly discussed the issues identified and reported that the Noise Subgroup would be refining this list and placing them into major issue categories. In addition, he mentioned that some framework issues were identified and these would be passed to the Framework Group.

Following the presentations, the working groups were reconvened.

VIII. Reconvene Working Groups

Following the reports to the plenary, the working groups reconvened to address the previous day's findings and the issues identified for discussion in the Workshop Agenda. The following represents a synopsis of Wednesday's activities.

In the Technology Breakout Group's discussion of noise, the participants wrestled with the problem of the subjective nature of what is an acceptable level of noise and what is not acceptable. They noted that factors such as background noise, time of day, and frequency all affect "acceptability". The use of LDN (aka DNL) was felt to be overly simplistic and did not assure "acceptability".

In its discussions about emissions, the Technology Breakout Group discussed the trade-offs in the emissions area--how emphasis on reducing one type of emission (e.g. NO_x) might have adverse effects on other emissions, such as CO_2 vs. decreased fuel efficiency. A related issue was local NO_x versus total NO_x and CO_2 and the trade-offs between performance in the take-off-landing cycle versus cruise performance, and so forth. They did agree that it was important to get a better base of scientific understanding in order to more fully comprehend the implications of various trade-offs.

The Technology Breakout group subsequently broke into subgroups. One group concentrating on noise issues and the other group applied its efforts on emission issues. The use of two subgroups essentially continued for the remainder of the workshop.
The Noise Subgroup discussed the issues developed during the previous day's session, with the intent of placing them into nine major issue areas.

Report of the Noise Working Group:

There were several overriding views expressed the workgroup participants. They included the opinion put forth that noise can restrict the growth of aviation if the level of complaints from communities around airports is not addressed. There was also general recognition that everyone involved has a part to play and that everyone needs to pay to achieve the goals put forth. In addition, there was general agreement that the acceptable levels of noise [and emissions] have not yet been determined.

The Report of the Noise Working Group was organized into key issues. For each of the issues a number of key factors or questions were identified that are important to understanding and consideration of the specific issue. For example, the first issue "Clear Definition of Noise Goals" included factors such as--Reasonable Attainable Goals; Is there a physical noise floor? Or Ramp noise reduction; etc. Subsequently the Impacts of each issue was analyzed, and finally, the question, "How do we make these fit within NASA goals?" Each of the Issues identified by the working group is analyzed using this structure.

Subsequently the working group ranked each of the issues in terms of its priority among the group. This ranking provides an indication of the priorities of the group for discussion at the second workshop. For example, the impact of population growth and the impact of air traffic growth are listed as two of the more relevant issues. The final section of the report contains some preliminary expectations for the second workshop.

The Noise Group's understanding of NASA's Program Goals and Objectives was as follows:

NASA Objective: To protect community welfare and health with an adequate margin of safety.

NASA Program Focus:
- Reduce perceived noise by 10 dB in 10 yrs, and by 20 dB in 20 yrs
- Shrink noise footprint within airport boundary
- Develop Scenarios:
  - range
  - realistic
  - use to test 10-20 dB
  - bring to communities
- Nationwide or worldwide?

Scope/magnitude/Timing:
- Examine whether 10 EPNdB + 20 dB is sufficient, given airport growth constraints
- 55 dB

Open issues regarding NASA's goals:

- Fleet competition and turn-over
- Land-use
- Flight operations
- Mitigation

Following are the issues charts that were developed by the Noise Working Group.

Clear Definition of Three Pillar Noise Goals

Issue	Impact	Action Required to fit with NASA's Goals
♦ Reasonable attainable goals ♦ Is there a physical noise floor? ♦ Ramp noise reduction ♦ Cabin noise reduction ♦ Identifying technology baseline (to measure goals against) ♦ Definition of constraints in achieving goals ♦ Vehicle classification (HSCT, AST, rotorcraft, etc.) ♦ Measure of success ♦ Mission ♦ Low background noise of the future	♦ Step change (paradigm shift) ♦ Affect strategy ♦ Affect final product ♦ Affect noise metrics ♦ Affect product mix ♦ Affect how money is applied ♦ Affect perspective (e.g., community)	♦ Adds clarity

Metrics: Ability to Predict Influence of Noise on People

Issue	Impact	Action Required to fit with NASA's Goals
♦ Vehicle classification ♦ Single event vs. average ♦ Noise character ♦ Sound quality	♦ Affects focus of research to meet metric ♦ People will hear a/c but won't be annoyed by sounds ♦ Ability to measure benefit of noise control tech ♦ Incorrect metric will produce misguided research/solution ♦ (Dick L. of DFW, disagreed with above statement)	♦ Quantify our goals and define strategies

Certification/Regulations

Issue	Impact	Action Required to fit with NASA's Goals
♦ Noise certification limits in the future ♦ Local rules ♦ Certification process	♦ Current cert may not appease public (Should it?) ♦ Affect cost to businesses ♦ Technology guides future rules and vice versa ♦ Certification provides tool to judge progress in technology ♦ Provide enabling capabilities to achieve NASA goals	♦ Reduce the need for proliferation of local rules

Adequate Research Infrastructure Capabilities

Issue	Impact	Action required to fit with NASA's Goals
♦ Methods to accelerate technology development ♦ Improved/credible noise prediction tools ♦ A step-change technology ♦ Sonic boom ♦ Major new research facility requirements ♦ Improved analytical & expert modeling techniques ♦ Facility background noise (will have to be low) ♦ Scarcity of noise experts ♦ Advanced instrumentation (sensor technology) ♦ Test facilities	♦ If we're weak, won't achieve goal ♦ Will lead to more competitive vehicle ♦ Affects decision of choices ♦ Provides flexibility and innovation ♦ Improves diagnostic capability ♦ Reduces cost, time and risk ♦ Accelerates technology development	A. Will provide enabling capability to achieve NASA goals

Implementation Issues

Issue--	Impact	Action Required to fit with NASA's Goals
♦ Retrofitability of solutions	♦ May take time and cost to do Implementation cost maybe an order of magnitude more than that for noise reduction	♦ Direct effect on timing into fleet
♦ Installation issues UHBPR engines (BP ratios>10)	♦ May lead to premature retirement of current aircraft	♦ Prioritize technology
♦ Time from research to implementation	♦ More options for noise reduction (systems approach)	
♦ A/C /engine integration (system approach)	♦ Transition technology faster (systems approach)	
♦ Trade-off between noise & other performance criteria	♦ Effectiveness of integration will affect manufacturer's acceptance adoption	
♦ Producability of noise reduction methods	♦ May impact National Airspace System (novel concepts may impact issue)	
	♦ Reduced cost of travel (ReCAT)	
	♦ Much more complex issue	
	♦ Retro. can accelerate total fleet noise reduction	
	♦ Will require multi-disciplinary team	

Cost-Benefit of Achieving NASA's Goals/Economics

Issue	Impact	Action Required to fit with NASA's Goals
♦ Airline economic growth	♦ If too costly, no implementation	♦ Benefit to community & aviation industry
♦ Affordability	♦ Will require seed money (investment)	
♦ Cost of noise reduction	♦ Airlines will grow	
♦ Cost of research	♦ Reduce blocktime	
	♦ 24-hr/day operation of the fleet	
	♦ Increase capacity	
	♦ Affects Reliability & Maintenability	
	♦ Reduce cost of land-use measures	
	♦ Improved aerodynamic performance	

Framework issues for next workshop

Issue	Impact	Action required to fit NASA's Goals
♦ Source control vs. residential control (7) ♦ Noise reduction vs. safety (2) ♦ Education of public (7) ♦ Who should pay? (65 or 55 LDN) (7) ♦ Non-acoustics (virtual) noise ♦ Impact of population growth (8) ♦ Air traffic growth (8) ♦ Public response methodology (1)		

Strategies

- ♦ Unconventional airframes & engines
- ♦ Low frequency noise for vibration problems
- ♦ Noise as an airframe design noise parameter
- ♦ Source noise reduction
- ♦ Innovative acoustics liners
- ♦ Balance betw base & focus program
- ♦ Flight operations
- ♦ Advanced active control
- ♦ Resource allocations: engine vs. airframe
- ♦ Broad systems approach
- ♦ Fixed design vs. adaptable design
- ♦ Gap assessment
- ♦ Re-engineered ATM to include noise issues
- ♦ Noise as a design driver or controller

Major Noise Issues

- ♦ Clear Definition of Noise Goals
- ♦ Metrics: Ability to Predict Influence of Noise on People
- ♦ Certification/Regulations
- ♦ Adequate Research Infrastructure Capabilities
- ♦ Implementation Issues
- ♦ Cost-Benefit of Achieving NASA's Goals/Economics
- ♦ Strategies
- ♦ Framework

Expectations for Workshop II
(Noise Group)

Identify:

- · Step Changes
- · Technologies to Achieve Goals
- · Benefits & Risks for All Interested / Affected Parties
- · Technological Barriers

Tasks:

- Run Scenarios Paper Airplanes to get some sense of 55 dB Contours on Airport
  - Large Airport
  - Medium Airport

REPORT OF THE EMISSIONS WORKING GROUP

During the Emissions Subgroup deliberations, the working groups addressed the morning's plenary comments; determined information requirements; prepared a report for presentation at the concluding session of the workshop; and finally, defined actions for SAIC, NASA, and the Working Group. The Emissions Working Group formulated four questions to help focus their discussions and organize their findings. These were:

1. What should high level NASA program objectives be? (e.g., reduce climate change effects ?)
2. What should NASA programs focus on? (CO2 or other effluents?)
3. What are the appropriate metrics for the scope, magnitude and timing of the reductions?
4. What other key technical questions need to be addressed?

Using these questions, the Emissions Working Group developed the matrix provided below to organize their information and present their findings. The findings were further identified as to their relevance to three different classes, namely, 1) ozone layer protection; 2) local air quality, and 3) global climate change. This information is contained in the tables below. The group also identified a number of over arching questions and issues that needed to be addressed at the next workshop.

Emissions Report

	Ozone Layer Protection	**Local Air Quality**	**Global Climate Change (CO_2 and all other GCC agents)**
What should high level NASA Program Objectives be?	· Provide technology so aircraft do not have a significant impact on ozone layer · No change in ozone layer from today · Return ozone layer to pre-Montreal protocol levels by 2030	· Develop technology that enable aircraft to contribute to improvements in LAQ independent of growth of air traffic · Develop technology that helps improve LAQ · Develop technology that reduces current LAQ impact of a/c · Reduce NO_X & VOC without adversely affecting other LAQ emittants	· Help US achieve its GCC goals · Develop technology that ensures a/c are compatible with GCC goals · Develop technology that helps US industry in negotiation and trading in addressing GCC issues · Research programs that assists policy makers to determine what technologies are feasible to address: GCC US as a technological leader in marketing these technologies worldwide

	Ozone Layer Protection	Local Air Quality	Global Climate Change (CO_2 and all other GCC agents)
What should NASA Programs' Focus be?	· NO_X · Sulfur/Aerosols · Ozone chemistry and transport · Atmospheric models & assessments	· LTO · NO_X & VOC · CO · Toxins	· Reduce fossil fuels burned · Continued scientific assessments of aviation's affects on GCC · Look at relative research, focus on CO_2, NO_X, clouds to ensure unintentional impacts are avoided · Look at relative importance of CO_2, NO_X, clouds on GCC · Try to reduce fossil fuel burned and not increase other important emitters
Scope/ Magnitude / Timing of reductions	· 'Practical' lower limits achievable · Projected no impact from climate models · Look at level of emittants resultant impact on health to determine 'acceptable' realm · Look at range of fleet models - subsonics, supersonics · Define appropriate metrics · 2030 to return ozone layer to pre-CFC state	· Timing set by rate & growth · What *can* technology do? · Reduce NO_X by 35% by 2003 – local goals further reduction for 2010	· Shorter term: reduce fossil fuel burned · Longer term: more aggressive reduction levels that might be beyond feasible fossil fuel burned reduction · Strongly link to Kyoto Protocol & air traffic growth rate · International influence need to be assessed: push by Europe/Asia · Strong links to Kyoto will accelerate timing—need to look at more clearly · Quantum leaps needed · Magnitude and timing are strongly linked · As much reduction as possible as soon as possible – NASA should assess this for feasibility

	Ozone Layer Protection	Local Air Quality	Global Climate Change (CO_2 and all other GCC agents)
Key Technology Issues	· Minimize cruise NO_X to lowest practical level (e.g. considering cost, safety, other environmental impacts) · Low/zero sulfur fuels development that is practical for worldwide aircraft use · To incorporate	· Minimize landing/take-off NO_X, VOCs to lowest practical level · Flexible in response to temporal & local variations in air quality · Minimize effluents during ground operations · Develop aircraft and operations to allow	· Identify fundamental (practical & feasible) limits for conventional hydrocarbon fuels ♦ aero/structural/ops ♦ operation · For practical aircraft system, various subclasses of aircraft: ♦ large transport, rotor, blimps · Identifying technical feasibility of practical non-conventional fueled combustion-based

	Ozone Layer Protection	Local Air Quality	Global Climate Change (CO_2 and all other GCC agents)
	potential environmental (ozone) impact into flight planning ***Better scientific understanding & ability to model is desired (Framework science issue)***	for growth while still responding to proposed framework challenges ***Action Item: Framework: Should we worry about soot, CO, SO_2,…?***	aviation · Look at new holistic problems that might arise · Given decreased CO_2 and increased traffic, define technology mix as a function of time

Additional (Over-arching) Questions/Issues:

1. Need to look at trade-offs among emittants and environmental impacts
2. Need to look at affordability and economic feasibility/investment level & timing for all technology developed
3. Look at a range of fleet models – subsonic, supersonic.
4. Need to define appropriate metrics
5. Useful to explore further what levels/impacts of emittants on environment are 'acceptable'.
6. Don't want to limit aviation growth IF we can address environmental issues.
7. Need to look at longer-term solutions/technologies beyond current fossil fuel systems.
8. Faster development & certification times:
    - ♦ development
    - ♦ retrofit challenges
    - ♦ fleet penetration
    - ♦ while economically feasible, practical, manufacturable, durable, etc.
9. Coupled constraints
    - ♦ trades
10. System-level design & analysis tools
11. New laboratories, facilities, expertise, as scope of solutions broaden.
12. Closer integration of technologies/regulators/environmental NGO
13. New technologies and procedures must be compatible with decreased noise objectives and solutions

Finally, there is a list of questions that should be considered in future meetings of the Emissions Workgroup.

QUESTIONS & PREPARATIONS FOR FUTURE WORKSHOPS: (LOCAL AIR QUALITY)

I. EPA study to determine role of airport in local air quality, additional information from EPA website.
II. Re-visit 'Flying Off Course'.
III. ICAO Working Group 3 references.
IV. Landing/take-off calculations showing relative contribution of various aircraft and flight segments
V. Estimate of max achievable from ops with current a/c fleet.
VI. FAA Advisory Circular on emissions
VII. Can we provide IPCC Tech Chapter?
VIII. NASA Assessments

IX. Homework assignments prior to workshop. (position papers)

QUESTIONS & PREPARATIONS FOR FUTURE WORKSHOPS: (OZONE LAYER PROTECTION)

I. Change achievable for state-of-the-art LO-NO_X combustors for aircraft
II. Articulation of current national EPA strategic ozone page
III. Papers on low sulfur and alternative fuels

QUESTIONS & PREPARATIONS FOR FUTURE WORKSHOPS: (GLOBAL CLIMATE CHANGE)

I. Mitre report - fuel savings from CNS/ATM exercise
II. Emission distribution model—to look at large levels
III. NASA study—total world fleet CO_2 emissions
IV. Cost/benefit info lacking—can anyone help?
V. Max achievables system study – NASA.
VI. Better articulation of Kyoto protocol goals
IX Reconvene plenary for Working Group Reports

The restructuring of the working group reports into two separate categories of emissions and noise, reflected the participants' view that the issue categories (emissions and noise) were a more logical form of organization. This allowed them to make better use of their expertise and interests than did the original organization into framework and technology issues.

IX. Rapporteurs 'impressions"

Frank Murray stated that in coordination with Howard Wesoky it was decided that a more youthful impression of the Workshop happenings would be presented under this Agenda Item, rather the more traditional rapporteur summary. Cindy Newberg and Don Sutkus were asked to be the "Rapporteurs" and they generously accepted this tasking. The following represents Cindy's and Don's impressions.

Impressions

Pros	Cons
Alphabetical seating	More details than just an agenda would have been useful (short desired outcomes)
No identifiers on the name tags -- removes predispositions (even while we quickly learned where we were from)	Have the facilitators interview a range of stakeholders in advance to give them a sense of the issues to provide a rounded vision
Efficiency of recording	
General meeting moved smoothly	
Number of participants in meeting seemed correct	
Length of meeting seemed correct	
Ability to brainstorm*	Need to recognize when to switch gears, hold sidebar discussions, to redirect/refocus the group*

Substance

- Change in approach: from single point and single aircraft/engine designs to considering total impacts and multiple regimes (e.g., LTO NO_x and Cruise NO_x)

- The term "framework" was difficult to assimilate – seems to be policy framework but was that it? Everyone understood what "technology" meant (thought there were questions regarding whether it was limited aircraft technology).

- Wide spectrum of participants:
  - the organizations that were represented
  - the background of the individual participants
- yet we still lack certain key stakeholders (e.g. airlines and state/local representation)

- Sensed frustration from those that have either reached an impasse or may see limits in what can be achieved

- Saw a new degree of cooperation

- Witnessed unlikely partnerships

- Different terms and metrics to measure the same overall impacts demonstrated the diversity of the group and lack synergy

- There was agreement.:

  - on a range of environmental impacts (stratospheric ozone protection, climate change, local air quality) that need to be considered in NASA's research program
  - that generation of technologies to reduce emissions is critical

  - that future aviation growth need not be constrained if technological solutions can be identified

  - need to consider what the maximum achievable technological limits are to ensure that we are considering all paths

X. The Way Forward - Frank Murray, Howard Wesoky

Frank thanked the chairpersons from the working groups for their outstanding efforts during the Workshop. He then related the following Eric Hoffer quote: "We often fail to realize how much we are influenced by those we argue with. They force us to reassess and rethink our preconceived assumptions and positions." Frank's perception was that the participants in the breakout groups really listened to each other and considered the various viewpoints. He thought that the Workshop provided an excellent start for the follow-on efforts and identified future directions to be addressed at the next two workshops. Following these brief remarks he turned the meeting over to the NASA sponsor, Howard Wesoky.

Howard thanked Frank for his excellent chairmanship and reiterated that he also thought that the last 2 _ days had been very productive in leading the way for future discussions and ultimately identifying future directions for NASA. He specifically thanked all presenters and mentioned that the term public interest organizations would be changed to NGO (non-government organizations). He felt that this change would more properly identify the organizations participating in the workshops because their interests went beyond just the public interest aspects. Howard mentioned that the next two workshops would take place

May 19 through 21 in Cleveland and that the third workshop would be in the San Francisco area July 7 through 9. Howard also reviewed the objectives and goals of the workshops and this viewgraph is attached to these minutes as "Workshop Goals." He also stated that an attempt would be undertaken to include more operators in the next workshops. Several of the participants had mentioned that this was a lacking in the attendance make up of this workshop and their input was needed. Following these remarks, Howard thanked all participants and expressed the hope to see all again at the Cleveland meeting.

Howard adjourned the meeting.

Environmental Compatibility
Workshop II
Summary Report

This is a Summary Report of the second in a series of three NASA Environmental Compatibility Workshops addressing the environmental impacts of aviation. At the first workshop the participants developed a list of major issues relating to aircraft emissions and noise that they believed had to be addressed. These issues helped to provide a partial answer to one of the basic questions placed on the table for the workshop to address, namely, what are the impacts of aviation noise and emissions on the environment? For the second workshop the participants were given the task of proposing new concepts and technologies that could help to mitigate the anticipated impacts of noise and emissions from the growing aviation industry.

The second workshop was organized into three parts: the first part consisted of presentations and discussion of topics that the participants had requested at the conclusion of the first workshop. These included topics such as global climate change, innovations in air traffic management and its impact on aircraft emissions, and zero emission aircraft. The FAA gave two presentations: one regarding the role in certification and regulation and future ICAO work programs, and the other addressing the importance of environmental research and the coordination of FAA and NASA programs.

The second part of the workshop focussed on a series of presentations by NASA. These presentations described the likely scenarios for future growth in aviation, the levels of emissions and noise under varying assumptions as to growth, technology advances and the composition of the fleet of aircraft. NASA then proceeded into a discussion of GAP Analysis; that is, an assessment of the goals that have been set for emission and noise reductions in the future, and the technology advances needed to achieve these goals under the various scenarios that had been presented. NASA also identified the expected impacts their current research programs will have on noise & emissions.

The challenge facing NASA was to develop a "Roadmap", that is, a plan to reach the objectives set forth in NASA's Three Pillars Goals. These goals call for the reduction of emissions of future aircraft by a factor of three within 10 years and by a factor of five within 20 years. They also called for a reduction of the perceived noise levels (when compared with today's subsonic aircraft) of future aircraft by a factor of two within 10 years, and by a factor of four within 20 years. The Roadmaps would identify the specific objectives of the technology development efforts needed to achieve the goals, their timing, and technical content.

These NASA presentations set the stage for the third and most important part of this workshop. In this part the participants were asked to brainstorm and come up with new concepts and ideas to meet the challenges identified in the GAP Analysis. To make the assignment more manageable, the participants were organized into Noise and the Emission Breakout Groups. Subsequently each of these breakout groups split into smaller working groups to address specific areas rather than attempt to analyze the noise or emissions problems in two large breakout groups.

The Emissions Breakout Group split into subgroups to look at propulsion, airframe, combustion, and ground and flight operations. In each of these subgroups, the participants looked at near-term, mid-term and far-term enabling concepts and enabling technologies. Each of these groups identified a number of concepts and technologies, such as ultra-high pressure and temperature cores; hi-temperature fuel systems; hybrid engine systems; metal/ceramic/polymer matrix composites; hydrogen fuel cells and a number of others. A complete listing of the concepts and technologies for each of the emissions subgroups is referenced in the Minutes of the Meeting in the report of the emission breakout summary. The Minutes of the Meeting can be found on the Environmental Comparability Research Workshop website.
(http://www.hq.nasa.gov/office/aero/oastthp/programs/encompat/encompat.htm)

The Noise Breakout Group also split into smaller groups that addressed source noise reduction, modeling and operations. These groups identified four broad technology systems: integration and modeling, propulsion systems, airframe, and air space operations. For each of these areas they focussed on the two time frames identified in the Three Pillars Goals, the years 2007 and 2017. A broad list was generated for each of the technology systems and each of the time windows.

Toward the end of the second day, spokespersons from each of the Noise and Emissions Breakout Groups presented the findings of their group to the others. This provided all of the participants the opportunity to become aware of the kinds of concepts that were being developed in the other group. During these exchanges it became apparent that some of the ideas for reducing noise might well increase emissions. Conversely, recommended concepts to reduce emissions might also have detrimental effects in terms of increased noise. There was widespread recognition in both groups that some method of identifying and weighing tradeoffs between these two objectives was needed.

After the breakout sessions the participants met in Plenary on the last day of the workshop to review and discuss their findings and recommendations. Each of the breakout groups expressed similar ideas in terms of "where we needed to go" (what steps should be taken next). System studies are needed to evaluate and prioritize the technology. This includes cost vs. benefit analysis and the establishment of figures of merit for grading the technology recommendations. Each of the technology options should be mapped into the Roadmap to identify the potential benefits that are expected. The technology readiness levels also need to be estimated, and this information worked into the Gap Analysis. Likewise deployment estimates would assist in understanding the relationship between single aircraft improvements and specific goals for emissions or noise. There exists a need to understand which emissions technology options have potentially negative impacts on noise and which work symbiotically. Similarly the identification of potentially negative impacts of emissions technology options on noise also need to be analyzed.

At the closing session it was worth noting that two normally disparate camps expressed similar concerns that the "wind down" of the AST program and the decrease in funding will occur before new research programs can be started. This could result in a breakup of the research teams and the destruction of program continuity. They both noted, "You can't start and stop research like that."

At the conclusion of the workshop Howard Wesoky referred back to the original four questions that had been posed to the participants at the first workshop. He noted that while these questions have not been answered fully, we have made significant progress down that path. He then gave his views as to where he believed the workshop stood in terms of answering these questions.

Question #1: "What are the impacts of aviation noise and emissions on the environment? He noted that we had discussed these in the analysis of the various scenarios earlier in this workshop. Question #2: "How do you believe those impacts may affect the growth of aviation? While no one had expressed the belief that aviation's growth should be stopped, he noted that the possible degree of noise and emissions mitigation certainly has a wide range. Question #3: "Must the growth of aviation lead to increased environmental impacts? He reiterated his opinion that this may be the key question. He added, "in the short or medium run the scenarios seem to indicate that the impacts will likely increase, even with new technologies. In the far run he indicated that noise levels are manageable with new technologies. His outlook for emissions was less optimistic. In the near and mid term as long as we rely on hydrocarbon fuels for aviation, we will face difficult problems in meeting the emissions goals. Even increased efficiency through the use of improved technology will not reduce emissions sufficiently to keep pace with increasing demands for air travel. In the far run the outcome is less clear…." Question #4: "What is the relationship of NASA's noise and emissions goals to aviation's impact on the environment?" He expressed the view that he hoped these goals would satisfy everyone's concerns, however, he noted that the goals are both dramatic and somewhat ambiguous,

thereby allowing for later development of clearer definitions for each of the specific enabling technology areas.
In closing Howard noted that NASA would review the concepts and ideas that had been generated by the workshop and comment back to the participants at the next workshop. In the interim NASA management would be starting its formal planning review process. Howard stated that he would provide an update on that process at the next workshop.

During the course of the Cleveland Workshop, a number of participants remarked that it was important to establish some method for continuing the dialogue and exchange of information among the various interest groups. The participants were asked to give some thought as to how such an exchange of views might be continued beyond this series of workshops. They were also asked to identify the kinds of information that would be most useful for their needs and the needs of their constituents. This topic will be placed on the agenda for discussion at the third and final workshop of this series, scheduled for July 7th through 9th in Monterey, California.

NASA ENVIRONMENTAL COMPATIBILITY RESEARCH WORKSHOP II
Cleveland, OH
May 19 –21, 1998

Agenda

Tuesday, May 19, 1998

7:15 a.m.	Breakfast in the Embassy Suites Atrium Café	
8:00 a.m.	Welcome and introductions: Comments on Workshop I	Howard Wesoky
8:15 a.m.	Housekeeping and administration	Frank Murray
	Website Information	Adina Cherry
	Agenda for Workshop II	Frank Murray
8:30 a.m.	EPA Study of Airport Local Air Quality	Bryan Manning (EPA)
	Comments and discussion:	Sue Gander (CCAP) Steve Morford (P&W)
9:30 a.m.	CNS/ATM Enhancements to Reduce Aircraft Emissions	Diana Liang (FAA)
	Comments and discussion:	Howard Aylesworth (AIA) Cindy Newberg (EPA)
10:15 a.m.	Break	
10:30 a.m.	Where do we go from Kyoto?: Aviation and Global Climate Change	Paul Stolpman (EPA)
	Global Climate Change: A White House Perspective	Steve Seidel (White House)
11:30 a.m.	Noise:	
	Certification and Future ICAO Work Program	Thomas Connor (FAA)
	Worldwide Impacts	Ben Sharp (Wyle)
	Comments and Discussion:	Dick Linn (DFW) Betty Ann Kane (NOISE)
12:45 p.m.	Lunch	
2:00 p.m.	Coordination with FAA "Environmental Research Beyond 2000"	Jim Littleton (FAA)
3:00 p.m.	Scenarios for Aviation's Growth: Opportunities for Advanced Technology	

	Noise	Ty Marien (NASA)
3:30 p.m.	Break	
3:45 p.m.	Scenarios for Aviation's Growth: Opportunities for Advanced Technology (cont.)	
	Emissions	Mark Guynn (NASA)
	Zero Emissions Aircraft	Chris Snyder (NASA)
4:45 p.m.	Adjourn	

Wednesday, May 20

7:15 a.m.	Breakfast in the Embassy Suites Atrium Café	
8:00 a.m.	Gap analysis and Roadmaps: Proposed Research Objectives and Activities	
	Introduction	Howard Wesoky (NASA)
	Noise	Dave Stephens (NASA)
	Emissions	John Rohde (NASA)
9:30 a.m.	Discussion of Meeting the Needs, Identifying the Concepts and Recommendations for Road Maps	
	Organization and assignments for breakout sessions	Frank Murray
9:45 a.m.	Break	
10:00 a.m.	Breakout sessions: (Sidebar groups to be used for brainstorming advanced concepts.)	
	Emissions	Carol Russo (NASA) Discussant
	Noise	Doug Dwoyer (NASA) Discussant
12:00 p.m.	Lunch (provided)	
1:00 p.m.	Breakouts reconvene	
3:00 p.m.	Break	
3:15 p.m.	Return to breakouts	

4:00 p.m.	Group Leaders exchange Emissions and Noise status	
4:30 p.m.	Finalize Emissions and Noise Reports	
5:00 p.m.	Adjourn	
Thursday, May 21		
7:15 a.m.	Breakfast in the Embassy Suites Atrium Café	
8:00 a.m.	Noise report and discussion	Doug Dwoyer (NASA) Facilitators
9:15 a.m.	Emissions report and discussion	Carol Russo (NASA) Facilitators
10:30 a.m.	Break	
10:45 a.m.	Impressions	Cindy Newberg (EPA) Don Sutkus (Boeing)
11:15 a.m.	The Way Forward	Frank Murray Howard Wesoky (NASA)
12:00 p.m.	Adjourn workshop	
1:00 p.m.	Lewis Research Center Tour Meet in Hotel Lobby	John Rohde (NASA)

Minutes of the NASA Environmental Compatibility Research Workshop
HELD MAY 19-21, 1998
AT THE EMBASSY SUITES HOTEL, CLEVELAND, OHIO

The following persons attended this Workshop.

First	Last Name	Company
Krish	Ahuja	Georgia Institute of Technology
Richard	Antcliff	NASA Langley
Thomas	Auxier	Pratt & Whitney
Howard	Aylesworth	Aerospace Industries Association Of America
Peter	Batterton	NASA Lewis
Kevin	Black	United Airlines
David	Bowles	NASA Langley
Steve	Bradford	FAA
Gerald	Brines	Allison Engine Company
Lawrence	Butler	GE Aircraft Engines
Carol	Cash	GE Aircraft Engines
Adina	Cherry	SAIC
Kestutis	Civinskas	NASA Lewis
John-Paul	Clarke	Massachusetts Institute of Technology
Thomas	Connor	FAA
Vic	Corsiglia	NASA Ames
Art	Coulomb	ATA
Charles	Cowan	Cutler & Stanfield
Robert	Cuthbertson	The Boeing Company
William	Dalton	Allison Engine Company
Ruben	DelRosario	NASA Lewis
Barbara	Dillon	SAIC
Willard	Dodds	GE Aircraft Engines
John	Dodge	AlliedSignal
Sam	Dollyhigh	NASA Langley
Michael	Dudley	NASA Ames
Douglas	Dwoyer	NASA Langley
David	Fancher	GE Aircraft Engines
Rick	Fucik	Northrop Grumman
Sue	Gander	Center for Clean Air Policy
Glen	Gilyard	NASA Dryden
Phillip	Gliebe	GE Aircraft Engines
John	Goulding	BFGoodrich Aerospace
John	Graham	Los Angeles Airport
Mark	Guynn	NASA Langley
Richard	Halik	Port Authority NY/NJ
William	Haller	NASA Lewis
Peter	Hart	Allison Engine Company
Thomas	Hartmann	Lockheed Martin Skunkworks
Tim	Haskell	Nashville International Airport
Robert	Howard	Sverdrup/AEDC

Dennis	Huff	NASA Lewis
Lynae	Jacobson	SEATAC Airport
Rodney	Jago	SAIC
Betty Ann	Kane	National Organization to Insure Sound Environment
Barry	Kiel	AFRL/PRTC
Herb	Kuntz	Lockheed Martin
Richard	Lawrence	NASA Goddard
Chi-Ming	Lee	NASA Lewis
Diana	Liang	FAA
Anita	Liang	NASA Lewis
Dick	Linn	DFW Airport
James	Littleton	FAA
Gary	Machles	GE Aircraft Engines
Max	Malone	United Airlines
Bryan	Manning	EPA
Ty	Marien	NASA Langley
William	Marx	FAA
Doug	Mathews	Pratt & Whitney
Peter	McCallum	NASA Lewis
Richard	Miake-Lye	Aerodyne Research Inc.
Nicholas	Miller	Harris, Miller, Miller & Hanson
John	Mitchem	AlliedSignal
Stephen	Morford	Pratt & Whitney
Frank	Murray	SAIC Consultant
Cindy	Newberg	EPA
Richard	Niedzwiecki	NASA Lewis
Charlie	Parente	Northrop Grumman
Eugene	Peters	Landrum & Brown
Steven	Pflaum	McDermott, Will, & Emery
Clemans	Powell	NASA Langley
Carol	Quinn	NASA Lewis
Ronald	Ray	NASA Dryden
Lisa	Reuss	SAIC
Karen	Robertson	DFW Airport
John	Rohde	NASA Lewis
Carol	Russo	NASA Lewis
Dennis	Sawyer	TRW
David	Schein	Northrop Grumman
Stephen	Seidel	White House
Paul	Senick	NASA Lewis
Ben	Sharp	Wyle Laboratories
Belur	Shivashankara	The Boeing Company
Rickey	Shyne	NASA Lewis
George	Siple	Camp Dresser & McKee Inc
Glenn	Smith	NASA HQ
Chuck	Smith	NASA Ames
Brian	Smith	NASA Ames

Christophe	Snyder	NASA Lewis
Paul	Soderman	NASA Ames
David	Stephens	NASA Langley
Paul	Stolpman	EPA
Gary	Stowell	San Jose International Airport
Donald	Sutkus	The Boeing Company
Bob	Tacina	NASA Lewis
Len	Tobias	NASA Ames
Ian	Waitz	MIT
Donald	Weir	AlliedSignal
Gregory	Wellman	Landrum & Brown
Chowen	Wey	NASA Lewis
Timothy	Wickenheiser	NASA Lewis
William	Willshire	NASA Langley
Jia	Yu	BFGoodrich Aerospace
Isam	Yunis	NASA Lewis

The following represents a synopsis of the discussion at this Workshop as related to the published agenda.

Welcome and Introductions
Comments on Workshop I

Howard Wesoky opened the Workshop by welcoming attendees and then presenting the following remarks:

> Welcome and thanks for participating in the Second Workshop on NASA's Environmental Compatibility Research. I'm Howard Wesoky, Team Leader for Environmental Compatibility Assessment in the NASA Headquarters Office of Aeronautics and Space Transportation Technology.
>
> Having lived in Cleveland for 23 years before moving to DC, I can promise that you will enjoy this often unfairly maligned city. You may not be able to get a ticket for an Indians baseball game or for the world famous Cleveland Orchestra. But make sure that you see the Rock 'n Roll Hall of Fame and eat in a restaurant in the Flats along the now clean and fireproof Cuyahoga River. And, equally important, tour the NASA Lewis Research Center on Thursday afternoon. Lewis is important to Cleveland and, as NASA's center of excellence for aeronautical propulsion research and technology, also important to our nation.
>
> It's good to see that most of those who attended the first Workshop in Atlanta have chosen to join us again. In a few minutes, Adina Cherry will tell newcomers how information from Workshop I can be accessed on the World Wide Web. I hope that everybody who attended Workshop I has been able to review that material. Many thanks to the participants who provided their earlier presentations to Adina, and I encourage new participants to do the same.
>
> I'd like to just briefly review where we've been so far in the workshop process. Recall that we are continuing a path begun with the March 1997 publication of NASA's "Aeronautics & Space Transportation Technology: Three Pillars for Success." That document included "stretch goals" for aircraft noise and emissions:

- Reduce emissions of future aircraft by a factor of three within 10 years, and by a factor of five within 20 years, and

- Reduce the perceived noise levels of future aircraft by a factor of two from today's subsonic aircraft within 10 years, and by a factor of four within 20 years.

And, as stated in the "Three Pillars" brochure, which is available again here in Cleveland, both of these environmental goals have the requirement to be achieved without affecting safety or affordability.

NASA agency management has asked the Environmental Compatibility Assessment Core Team to assess the ability of current research and technology programs to achieve the noise and emissions goals, and to determine what additional effort may be required.

The ECoA Core Team Mission Statement"

In collaboration with carriers, manufacturers, academia and other government agencies, NASA will develop robust technology options with the objective that environmental issues do not constrain the growth of air transportation.

We began the workshop process by suggesting that the following questions would be addressed:

1. What are the impacts of aviation noise and emissions on the environment?

2. How do you believe those impacts may affect the growth of aviation?

3. Must the growth of aviation lead to increased environmental impact?

4. What is the relationship of NASA's noise and emissions goals to aviation's impact on the environment?

Before we leave Cleveland, I'll return to these questions and attempt to summarize our progress in seeking answers.

At Workshop I, we also discussed the 1995 White House report which suggested that environmental issues are likely to impose the fundamental limitation on air transportation in the 21st century. And, in response, we asked two other questions which we attempted to answer while in Atlanta. Those questions are shown here along with my very summary interpretation of your answers.

- What are the environmental issues that are likely to impose fundamental limitations on aviation's growth?
  - Growth in demand
  - Practical metrics
  - Cooperation of regulators, technologists and public interest
  - Emissions
    - Local air quality, global climate change, ozone layer protection
    - Tradeoffs among emittants
  - Noise

- » Appropriate goals, e.g., “floor” vs. “background”
- » Ability to predict subjective effects, e.g., single event vs. average

- What are the technical challenges faced in eliminating the fundamental limitations to aviation’s growth?
  - Invention/alternatives
  - Application of technology, e.g., retrofit
  - Affordability
  - Capacity issues
  - Research infrastructure

You may not agree with this summary, particularly if you are concerned about very specific noise or emissions issues. My good friend Howard Aylesworth more succinctly summarized Workshop I with only three points:

1. The objective is <u>not</u> to limit aviation growth,

2. Everyone must **“**pay some of the freight;**”** and

3. Acceptable levels of noise and emissions must be determined.

We’ll give each of you a chance to further consider these matters in tomorrow’s breakout sessions when we attempt to move the agenda towards recommendations for research and technology activities.

But now let me ask Frank Murray to again chair the Workshop and to discuss our agenda in detail. For newcomers, Frank’s credentials are on the Web in my Atlanta introductory remarks. He’s had substantial experience in dealing with energy and environmental issues as staff director for a congressional committee, as a lecturer at Georgetown University, and in the private sector. As before, I’ll rely on Frank to guide us for the next two and a half days while I try to concentrate on listening to you. Howard’s figures are included on the website as “Introductory Remarks”.

Housekeeping and Administration
Website Information
Agenda for Workshop II

Frank Murray reiterated Howard’s welcome to attendees and briefly covered meeting administration matters. He requested that all attendees fill out meeting registration forms identifying which group, “Emissions” or “Noise”, they would be attending. He also requested that those planning on attending a tour of the Lewis facility indicate their intent on the form.

Adina Cherry, SAIC’s overall meeting coordinator, provided an updated status of NASA’s website that identifies what information is available on the web, and indicated future plans for additional items.

Frank then reviewed the Agenda, giving a brief description of each item and how it fit into the overall purposes and goal scheme of the second Workshop. He also asked that any comments on the summary of the first Workshop (distributed with the Agenda of this meeting) be provided to him and said a revised summary would be included in the minutes of the second Workshop. Frank then proceeded with his opening remarks:

Howard discussed the four questions that were posed for the first workshop and the progress that has been made so far in providing answers to these questions. During the next few days we should move still closer to arriving at some conclusions and judgments as to our collective answers to these questions.

I have provided a Summary Report for the Atlanta Workshop. It contains my impressions of the findings of the workshop and in particular relies heavily on the closing session's reports of the breakout groups. I would ask that you read this short summary. If you have any serious problems with its contents please provide me with a copy of your proposed changes, or better yet, send me an email at fxmurray@erols.com. Please resist the urge to wordsmith the Summary and confine your remarks to egregious errors of omission or commission. It is quite possible that I did not fully appreciate the major thrust of your remarks. If so, I would like to provide you with the opportunity to correct the record.

For the Workshop series we had presented a schematic that provided a conceptual outline for the workshops. We have made some adjustments to that schematic to take account of the progress at the Atlanta Workshop and to reset our sights in light of your input. The revised schematic is shown on the screen. We are now looking to workshop II to "Review customer needs and benefits and to provide suggestions to build Roadmaps." Roadmaps are the terminology used to describe the NASA planning format. Howard will discuss these program-planning tools in more detail tomorrow morning.

Today we will devote some time to answering the mail. At the conclusion of your deliberations for the Atlanta workshop, you placed on the table a number of requests for additional information. I believe the staff has been able to pull together most of the information that you requested either by obtaining copies of reports or by contacting knowledgeable individuals to address the workshop. Since a major portion of this information will be provided in the form of presentations, I would encourage you to listen closely and ask questions. We have also asked some of your fellow workshop participants to get the ball rolling by commenting on a few of the presentations. Providing the information, which you requested at the First Workshop, will take up much of the first day.

Mid afternoon we will shift the burden to NASA. They will present information on the scenarios for estimating the future impact of aviation on the environment. These scenarios will be based on a number of key variables and assumptions that should also trigger some good discussion.

Then we will ask NASA to present the three pillars Goals that were introduced at the first workshop. I believe this will also trigger some discussion related to the translation of the general goals into specific performance criteria. We will then complete the NASA presentations with a discussion of the GAP Analysis, which is the difference between the environmental impacts provided by the scenarios and the targets presented in the goals. NASA will also introduce us to its "Roadmaps". These are the planning tools that the Agency uses in planning for research and demonstration programs in order to achieve its goals. They will provide some structure and organization for the types of information that is important in evaluating such advanced concepts.

Your primary job for this workshop will be to propose and discuss the concepts and approaches that should be considered to close this gap. Most of these deliberations and brainstorming will be undertaken in the breakout groups. And, if it makes more sense in terms of effectively utilizing our time, we will make use of some small discussion or drafting groups to look at specific areas of interest. We will leave this to the discretion of the discussion leaders and the breakout participants.

We have a very ambitious schedule ahead of us; and we have a lot to accomplish in the next two and one half days. So if there are no questions, lets get started.

EPA Study of Airport Local Air Quality

Bryan Manning presented a briefing on regional ground level emissions from commercial aircraft. He stated that many U.S. cities face significant air quality problems and that commercial aircraft are under increasing scrutiny since they are expected to comprise a growing proportion of regional emissions. He also stated that aircraft ground level emissions are one of the four most important environmental issues connected to airports. Since aviation is the fastest growing mode of travel in the country with 32 of the nation's 50 busiest airports expanding and new runways planned at 60 of the 100 largest airports, the emission problem if not countered, will exceed acceptable standards. Bryan also presented material on the health and environmental effects of air pollutants. Data was also provided on several non-attainment areas in the U.S. with preliminary results presented for five different air pollutants. Bryan summarized his presentation with four major points: 1) State and local air quality organizations have a critical need for significant NOx and particulate matter reductions from any and all source, 2) commercial aircraft's contribution to ground-level emissions is a regional air quality issue and should receive specific consideration, 3) growth in commercial aircraft is occurring when other emission sources are drastically reducing emissions, thereby accentuating the growth in aircraft emissions, and 4) commercial aircraft is a small but significant source of regional ground-level emissions. Bryan's briefing is available on our website under the heading "Local Air Quality Presentation, Manning/EPA".

Comments and Discussion

Sue Gander and Steve Morford provided some brief comments on Bryan's presentation at this point. Some of these comments were: 1) Revised operational procedures at airports become more important as air traffic grows: How is the international community addressing this issue? The response was that they are handling it on an airport basis whereas we are handling it on a regional basis. 2) Who provided the forecast data? The response identified the FAA as the provider. 3) Have economic factors been considered in the analysis? The response was "only superficially." 4) A final comment was that the FAA is now looking at other emitters in the airport environment e.g., power units, ground support equipment, etc.

CNS/ATM Enhancements to Reduce Aircraft Emissions

Diana Liang presented the following briefing, stating that the study objectives include the following:

- Develop preliminary estimates of fuel savings and resulting emission reductions resulting from CNS/ATM enhancements in the US.

- Results should identify the upper bound of savings that could be achieved in the best case situation.

Diana stated that the period of evaluation is 1996-2015 and covers CNS/ATM improvements in U.S. controlled oceanic airspace, CONUS en route and terminal airspace, and U.S. surface operations. Baseline and future national airspace scenarios were reviewed as well as the modeling scenarios used in the analysis. Diana also presented the assumptions, sources of data, fleet mix, results, and metrics of the study. She presented annual fuel savings by 2015 and subsequent reductions in NOx, CO, and hydrocarbons. Finally, the remaining schedule of this FAA activity was reviewed and other follow-on activities were described. The entire briefing, titled "CNS/ATM Enhancements to Reduce Aircraft Emissions", is available on the website.

Comments and Discussion

Howard Aylesworth and Cindy Newburg provided comments on the CNS/ATM presentation. Some of these comments follow: 1) Will variable growth rates be used in follow-on activities? The response indicated that this would be considered. 2) It was also mentioned that moving the CNS/ATM modernization effort forward would provide earlier favorable impacts. 3) Unimpeded aircraft taxiing procedures were mentioned as a significant reducer of local airport emissions, particularly NOx. 4) The point was made that most of the CNS/ATM benefits accrued above 3000 ft., which was identified as the cruise altitude in the study.

Where do we go from Kyoto? Aviation and Global Climate Change

Paul Stolpman presented a briefing on the White House and aviation sector activities related to Kyoto. The following is a synopsis of his presentation:

He related that industrialized countries of the world have agreed to cut emissions by 5.5% below 1990 levels by 2008-2012. Six different gases/emissions were covered and trading would be allowed for domestic and international compliance. Since Kyoto, President Clinton has submitted a $6.3 billion budget request for technology research and tax incentives. Ongoing economic and policy analyses are addressing costs associated with reaching the targets, the role of technology, and domestic and international emissions trading options. He went on to say that aviation emissions are becoming increasingly important from a number of environmental perspectives – urban ozone, stratospheric ozone depletion, and climate change. Whereas other sources are being or beginning to be controlled, aviation emissions continue to grow. In regard to the trading program, the Kyoto Protocol authorizes international greenhouse gas emissions trading for countries that made commitments. The U.S. plans to implement a domestic trading program for the 2008-2012 budget periods. “Rules of the game” still need to be developed and ratified and the U.S. will pursue meaningful participation on part of key developing countries. Paul stated that the President made this a condition of his submitting the Kyoto Protocol to the Senate for ratification. A key point made during this briefing was that the trading program would be a domestic as well as an international program.

Global Climate Change: A White House Perspective:

Steve Seidel followed Paul and stated that he was extremely pleased with what was being accomplished in these Workshops and thanked those present for their interest and support of this program. He stated that developing countries will increase their contributions to the emission problem and increasing attention will need to be paid to that fact. Resolution of this problem will continue to evolve. The ICAO Committee on Aviation Environmental Protection (CAEP) work program will analyze options for technology assessments, cruise based certification, best operating practices, and an accelerated CNS/ATM implementation program. Additionally, an evaluation of market based options will be addressed. Steve stated that CNS/ATM is significant in reducing fuel consumption but is not the only answer when it comes to reducing emissions. In regard to trading credits, no commitments will be made until 2008-2012 so trading won’t take place until then. The method or system for trading still has to be developed. No credits will be given until 2008. Steve again thanked NASA and Workshop participants for their support of this effort.

Noise:

Certification and Future ICAO Work Program

Tom Connor presented a briefing on aircraft noise control and the role of Federal research. In this briefing, he reviewed the regulatory documents pertaining to both national and international noise. He also reviewed the structure of the ICAO CAEP and the working groups supporting CAEP. He discussed the utilization of DNL for measuring noise in the airport environment and the breakouts of moderate, significant, and severe exposures as they relate to DNL decibel levels. He stated that the FAA's environmental R&D mission is to provide strong leadership in mitigating aviation's adverse impact on the public consistent with an effective aviation system. In describing FAA's environmental roadmap, he compared the program to a "three legged stool" with source reduction, abatement procedures, and land use planning providing the legs of the stool. The ultimate goal of the program is to provide a safe, efficient aviation system and protection of public health and welfare. Tom's presentation is on the Website and is identified as "Aircraft Noise Control and the Role of Federal Research".

Worldwide Impacts

Ben Sharp presented a briefing of a study conducted to forecast noise impact for 130 airports worldwide. The methodology utilized for this study relied on data from all scheduled world jet and turboprop passenger, cargo, and charter operations based on local criteria and metrics. Population impact was based on a worldwide population database, and generalized relationships for impact area vs. aircraft operations were developed based on the actual data received from airports in order to calculate impacted area at airports for which data is unavailable. Ben stressed that this methodology provides an estimate of the current and future aggregate world noise impact, and does *not* attempt to predict the actual noise impact at specific airports. Ben's presentation can be reviewed on the website under the title "World Airport Noise Impact Forecasts".

Comments and Discussion

Dick Linn and Betty Ann Kane provided comments on these presentations and the airport noise problem in general. The following represents a synopsis of the comments made under this agenda item. It was brought out under this comment session that the 55 DNL selection was made primarily because of economics. It was also mentioned that the NASA Advanced Subsonic Transport (AST) program is the prime contributor to noise reduction and that the current budget in AST does not allow for extensive testing. Furthermore, NASA will lose its extensive noise experience if this situation prevails. It was also stated that in order to achieve a 10-dB reduction "tweaking" would not suffice. Major changes in technology and operations will be required. FAA and NASA need more money if the goals are to be met in the timeframe specified. Dick stated that increased fuel prices would force the issue for additional and timely research. Finally, he provided copies of a paper he developed in response to several participants at the last Workshop. This paper, "Ramblings of an Old Aviation Enthusiast" is available on the Web.

Coordination with FAA "Environmental Research Beyond 2000"

Jim Littleton's presentation related that the goals of the FAA are to: 1) Remove/mitigate environmental impediments to aviation growth, 2) to achieve this goal with participation from all interested parties, and 3) identify R&D strategies that can resolve environmental impediments and fulfill FAA's environmental mission. Overall environmental strategies include: designing cost effective solutions; providing stakeholders a voice; serving as an advocate for both the environment and aviation growth; and promoting compatibility between environmental concerns and other areas of FAA research and policymaking. Since resources are limited--only two percent of the FAA's R&D budget--best use of these limited resources must be made. The research of the FAA and NASA compliment each other in that NASA does the basic research, proof of concept and technology feasibility, while the FAA regulates, provides policy and guidance, and attempts to balance the needs of all stakeholders. The ultimate goal then for the FAA is to

provide a focused, cost effective environmental R&D program for 2000 and beyond. A final remark made during this presentation was that the FAA is more involved with near-term issues while NASA is more concerned with future issues. This briefing in its entirety is contained on the Website under the title "Environmental Research beyond 2000" FAA/EEA.

Scenarios for Aviation's Growth: Opportunities for Advanced Technology

Airport Noise Study for Future Fleet Scenarios

The objective of this study was to examine the effect of inserting new technology aircraft that meet the Pillar One Noise Goal into the fleet at several airports, while at the same time allowing annual airport operations to increase. The purpose is to put bounds on the airport noise exposure problem.

Ty Marien began by describing the two scenarios that would be used for comparison purposes. For each of these he provided the key assumptions regarding the composition of the fleet of jet aircraft. The No Technology Scenario called for no technology improvement beyond 1997 out to the year 2050, however stage 2 aircraft would be removed by the year 2000. For the Technology Improvement Insertion Scenario stage 2 aircraft would be removed by 2000, then starting in the year 2007 all new aircraft entering the fleet would be 10dB quieter than the present technology, finally by 2017 all new aircraft entering the fleet would be 20dB quieter.

For these two scenarios the study then applied annual production and replacement numbers, technology introduction dates, and penetration levels. Based on these inputs the study looked at the results of two airports with different traffic profiles (mixes) of short haul, long haul and propeller aircraft and differing expectations as to the growth in each of these classes. The two airports studied were Washington Dulles International and Pittsburgh International.

The summary of the study showed the following: First, without additional noise reduction technologies, noise levels increase over time once the removal of Stage 2 aircraft has been completed due to the increased traffic projected at each of the airports. Second, noise reduction technologies have the potential to decrease the noise levels around the airports despite the increase in aircraft operations. Third, the benefits of additional noise reduction technologies will be limited unless quieter turboprop aircraft are introduced or replaced by quiet jets.

The detailed charts for Ty's presentation can be found on the website as "Airport Noise Study for Future Fleet Scenarios". Future study plans call for an extension of this study to more airports and adding differing scenarios. In addition further study will be undertaken to include rotorcraft operations.

Impact of Technology on Future Emissions

Mark Guynn presented a briefing of a study that assessed the potential impact of technology advances on future emissions. At the beginning of the presentation Mark identified several important caveats regarding the assumptions used in the study. First, NASA technologies used to project the future are at various levels of maturity and that after additional research some may be deemed impractical or less beneficial than anticipated. Second, the costs associated with both development and implementation have not been examined and these costs could be critical to the use of the technologies. Third, for these technologies to be viable they must be compatible with the other requirements of the Three Pillar Goals. The key parameter measured in this study is the consumption of fuel. This is estimated based on future projections of the type of aircraft in the fleet, and the growth in the volume of air travel and the travel patterns. Several different forecasts were run for the model each with different assumptions regarding the growth rates in aviation. These rates varied from 2% to nearly 4% annually during the period 1995 to

2050. The varying assumptions yielded fuel consumption increases by 2050 of between 150% and 190% relative to today's levels. The differences reflect the variety of projections regarding the volume of traffic, types of aircraft in the fleet, and technologies in use. Concurrently NOx emissions are projected to increase 30% to 250% by 2050 relative to today.

As part of the presentation several world maps were presented showing the traffic patterns and the amount of fuel burned in various parts of the globe. It is interesting to note that more than 70% of the fuel consumption currently takes place between 30degrees-north and 60degrees-north latitude. This includes most of the United States and Western Europe as well as Japan.

The summary provided four principle conclusions: First, projected advances in technology are not sufficient to counteract the growth in traffic. Fuel burn is projected to increase 150%-190% by 2050 relative to today and NOx emissions to increase 30% to 250% relative to today. Second, impacts of technology advances on future total emissions are a function of the opportunity for introducing new aircraft into the fleet. Third, the projections of fuel burn and especially emissions vary widely among the scenarios. Finally, NASA technologies to be viable must be compatible with other NASA Pillar goals, including affordability of air travel.

The briefing materials for Mark's presentation are identified on the website as "Potential Impact of Aircraft Technology Advances on Future CO_2 and NO_X Emissions".

Zero Emissions Aircraft

Chris Snyder presented a comparison of alternative systems (referred to as "zero emission aircraft") against a conventional baseline. This study was an extension of the preliminary work done by Waitz and Pannathur of MIT. Ian Waitz presented the results of the MIT study at Workshop I in Atlanta. At that time Ian acknowledged that his study needed greater depth and analysis before any significant conclusions about potential zero emissions aircraft could be drawn. Snyder's study, while far from comprehensive, provided that second look.

In his presentation, Chris described the key parameters of the baseline aircraft, such as maximum take-off mass, fuel capacity, design range, cruise thrust, range and passenger capacity. Against these key characteristics he then presented the estimated characteristics for various unconventional aircraft types with different fuel systems, such as hydrogen-fuel (liquid), nuclear powered and fuel cells. After explaining the assumptions that were made for the various aircraft systems, Chris then compared their key characteristics with that of the baseline aircraft.

For the liquid hydrogen system two versions were considered: one with fuel in the wings and the other with fuel in the wings and fuselage. The latter system was necessary if the operational range was to be achieved. (The version with the fuel in the wings could only achieve a little over two thousand miles in range.) The results indicated that the hydrogen aircraft would be bigger, but lighter. Placing liquid hydrogen fuel in the fuselage was believed to represent a major engineering challenge. One important drawback was that the current method of producing hydrogen was very polluting. A "free source" of hydrogen would have to be developed (e.g., a solar process) to achieve the environmental objectives.

The nuclear powered aircraft was felt to be a major challenge for several reasons. First weight for reactor shielding requirements was believed to be a major problem. However, the safety and acceptance difficulties were felt to be overwhelming. A combination of kerosene and nuclear (hybrid system) presented the same problems regarding acceptance and shielding plus had the added feature of NOx and CO_2 emissions.

The fuel cell powered system would provide zero emissions (depending on the source of hydrogen), however, using today's fuel cell technology, it would be a bigger aircraft (if it were to achieve a 6500-mile range) and it would be a heavier aircraft. Fuel cell performance was an unknown as current technology is sensitive to vibration and thermal cycling. This would be a challenge to propulsion system to engineers.

The end result of Chris' analysis indicated that with today's technology it is difficult to out perform a hydrocarbon fueled aircraft system. While other technology may hold promise for improved environmental performance, it will take considerable research and development before they are practical alternatives.

The briefing of Chris Snyder is on the website as "Scenarios for Aviation's Growth: Opportunities for Advanced Technology: "Zero Emissions" Aircraft".

Gap Analysis and Roadmaps: Proposed Research Objectives and Activities

Howard Wesoky, NASA, opened the discussion of GAP Analysis and Roadmaps by defining GAP Analysis in terms to the new objectives and programs that are required to achieve the three Pillar Goals. The Three Pillar Goals were described in terms of the emissions and noise levels of future aircraft. The emissions goals called for a reduction of total emissions by a factor of three within 10 years. The 20-year goal called for a reduction of emissions by a factor of five for new aircraft. The goals for perceived noise levels of future aircraft called for a factor of two reduction from the subsonic aircraft of today within 10 years. The 20-year goals called for new aircraft to achieve perceived noise level reductions by a factor of four.

Howard noted that these are very ambitious goals that cannot be achieved by a business-as-usual approach. To reach these goals NASA used "Roadmaps" to coordinate their research and technology planning. The Roadmap became a plan to reach an outcome. It contained the statement of objectives in terms meaningful to the development effort. It specified the timing of the key activities if the development plan was to achieve the goal. Finally, the roadmap specified the technical content of the program including the supporting or basic research that had to be accomplished if the plan was to be successfully completed.

At the broadest level the Roadmaps identified the objectives as the Three Pillar goals mentioned above, that is, to reduce emissions by a factor of five and noise by a factor of four. Also at the broadest level the Roadmaps specified the overall timing in terms of the 10-year and 20 year horizons. Against these time horizons the individual programs and projects would build their time schedules and milestones.

The technical content of the roadmaps was based on the needs identified to reach the goal within the time horizons. It was important to identify the technical areas of concentration; any revolutionary concepts and all the activities needed to effectively transfer the technology.

In summing up the GAP Analysis and the Roadmaps Howard reiterated the importance of revolutionary concepts in achieving the three Pillar Goals. "Business as usual will not achieve the Three Pillar Goals; we need new thinking and new ways of doing things. Evolutionary approaches, while helpful, will not get us there." He noted that it is important to do some out-of –the-box brainstorming to identify new approaches and enabling technologies.

Discussion of Meeting the Needs, Identifying the Concepts and Recommendations for Road Maps
Organization and Assignments for Breakout Sessions

The participants were divided into two major breakout groups, one for Noise and the other for Emissions. Each of these groups held a general meeting to discuss broad issues related to their particular areas of

concern. Ms. Carol Russo was the Discussant for the Emissions Group and Doug Dwoyer led the Noise Group. Following this general discussion by the Emissions and Noise breakout groups each of these groups split into smaller brainstorming and drafting groups according to the interests of the participants.

For example, Emissions divided into two groups dealing with propulsion and airframe technologies. Smaller side groups were used to address other questions that did not fit neatly into either airframe or engine, such as innovation in operations to improve efficiency. The Noise group was using similar smaller breakout groups one to address the technology concepts and the other to address operations. Concepts that could reasonably be expected to be available in the near term were developed. Likewise both groups also addressed concepts that were longer term in nature. The emissions group also discussed concepts that would likely be applicable to the mid 21st century.

Toward the end of this second day, Group leaders exchanged status reports with each other and their members so that issues could be shared and all participants would understand the status of both groups. At this session it was discovered that some proposed concepts involved potential trade-offs, in that, technologies proposed to reduce noise might have adverse effects on emissions or vice versa. Several such areas were identified and there was considerable discussion as to how such cases should be addressed. No resolution was reached at that time other than this potential problem needed to be considered in evaluating innovative concepts.

After this, the subgroups reconvened to finalize their reports for the next day's plenary session.

Noise Report and Discussion

Doug Dwoyer introduced the noise report and provided an overview of its discussions and results. He then asked the facilitators to present the specific findings. The noise reports are on the website under "Noise Breakout Reports". Some highlights of the noise report are provided below.

There was broad agreement that the targets for noise were to provide technologies to reduce perceived levels of aircraft noise by 10dB by 2007 and 20dB in 2017. Furthermore the group believed that it was important to improve the ability to predict the effects of noise on people. The group also agreed to focus on source noise reduction, modeling and operations.

Technology options provided a broad initial list for propulsion, airframe, air space operations and integration and modeling. For these technologies the time frame was related to the two target dates proposed in the three pillars goals.

Looking ahead several activities were identified that would require attention. Systems studies would be needed to evaluate and prioritize the technology options that were proposed; these would include cost and benefit analysis and the establishment of figures of merit. The potential benefits of the technology options would then need to be assessed and related to the Gap Analysis. Finally there needs to be some assessment to understand which emissions technology options have potentially negative effects on noise and vice versa. Proposed noise solutions cannot proceed without some consideration of the effects these may have on the aircraft emissions.

Comments by Betty Ann Kane:

Ms. Betty Ann Kane attended the first two days of the workshop but had a conflict that prevented her from presenting her views at the closing session regarding the work of the Noise Breakout Group. She did provide the following written remarks that were presented by Dr. Ajuha:

I am not able to be at the final sessions of the Environmental Compatibility Assessment workshop this morning, as I have to be in Washington for a previously scheduled meeting of the D.C. Retirement Board. As you have requested, I am providing some reflections on the workshop issues and process that you may share with the group. I look forward to being with you at the final workshop in California in July.

1. NOISE applauded the original announcement of the goal to reduce aircraft noise by factors of 10 dB and 20db by NASA Administrator Goldin last year, and we are very pleased to see the serious effort being made through the workshops to advise NASA on a research and development program to reach those goals. NOISE is pleased to see aviation noise recognized as a significant environmental problem that needs to be dealt with, and not dismissed as an "attitude" problem.

2. One of the most significant things that occurred in Cleveland was the FAA's admission that the 65 dnl level for noise mitigation was based on funding considerations, and that the 1974 EPA finding that 55 dnl was the proper level to use to protect the public health and welfare was correct and could be implemented if the gains from Stage 3 conversion are not allowed to erode.

3. The involvement of environmental advocacy groups is very important both to designing the research and development and to building support for the funding that will be needed to carry out the R & D. Every effort should be made to continue to reach out, inform, and involve this sector.

4. The big missing sector is the airline industry. They will be very important in gaining congressional support, as well as needed insight for the research and implementation. I would be willing to work with you to try to get more airline representation at the next workshop.

5. There are many parallels between the recommendations of the emissions group and the noise group. However, I was struck by an apparent lack of awareness of the noise implications, both positive and negative, of many of the emissions concepts.

6. Noise from helicopters, turbo props, and other small aircraft need to be included in the program because these are a growing source of community concern.

7. Technology makes progress solving environmental problems possible, but is only a part of the solution—regulation, enforcement, and economic and market incentives will also be needed. For example, technology made Stage 3 aircraft possible, industry made them economically feasible, but the law made the phase-out happen.

8. I share Dick Linn's concern for the wind down of the AST program, the reduction in current AST funding because they are being forced to pick up facilities charges, and the gap that will occur as AST phases out before the new program gear up. You can't start and stop research like that.

   Finally, but not least: This program will need very strong advocacy to succeed. Thought needs to be given as to how to make all the right stakeholders and decision makers aware and supportive and to get it moving as soon and as big as possible.

Emissions Report and Discussion

Carol Russo introduced the emissions report and provided a summary and overview of the findings. John Rohde was then called upon to present the technology concepts that were developed by the breakout group. The emissions reports are on the website under "Emission Breakout Reports". Some highlights of emissions report are provided below.

Specific emissions goals were proposed. Generally these goals pushed toward achieving the maximum reduction practical within the time frame of the three pillar goals. In addition, some targets for the propulsion element were proposed for NOx and CO2 (a 25% reduction in CO2 and a 67% reduction in NOx were proposed for 2007). For the year 2012 targets of a 50% reduction for CO2 and an 80% reduction in NOx were proposed.

In addition to the targets, the group developed a broad initial list of technologies and concepts for propulsion, airframe, air space operations, and integration and modeling. These concepts cover the short run, mid term and the long run (out to 2050).

In terms of "where we need to go" Ms. Russo noted that more work needs to be done to define specific emissions goals. Systems studies are required to affirm the maximum reduction practical, and emittants other than NOx and CO2 need to be addressed. Cost benefit studies and figures of merit will also be required to evaluate and prioritize the technology options and to map these in terms of the technology readiness levels and from there into the Gap Analysis.

Impressions

Cindy Newberg and Don Sutkus were asked to give their impressions of the workshop. Cindy led off this presentation by stating that she hoped the technique of seating participants alphabetically would be eliminated at the next Workshop. Some other impressions presented were:

1) Use of NASA facilitators was very effective in bringing out ideas and NASA-related activities;
2) hotel facilities were much better than Atlanta's;
3) Workshop structure and framework was improved;
4) use of the first day to address the first Workshop's issues was a good idea;
5) brainstorming was hindered by screening comments which led to the loss of some ideas;
6) fonts were too small on the computer generated presentations, and finally,
7) the web page is not being used to its full potential. Listing associated resources and contact points and getting material/charts on the web more quickly could result in better preparation for the next Workshop.

Don presented some suggestions for the third Workshop, summarized in the following comments:

1) Establish links to the atmospheric research community;
2) the Workshop should revisit the noise and emission goals to compare them to technologies, compare compatibility between noise and emissions tracks, consider feasibility/technology tradeoffs, and quantify benefit;
3) potential factors to bringing technologies to the marketplace should be considered;
4) the Workshop should continue to address the "issues list";
5) How will the conclusions of the Workshops be used and is there a role for the participants?
6) Finally, what are NASA's lessons learned?

The Way Forward

Closing Remarks by F. X. Murray

In his closing remarks Frank reviewed the following questions that had be posed as a guide for Workshop II.

1. Have the needs been met?
2. Have new concepts been put forward?
3. Have recommendations for strawman roadmaps been developed?

Skipping the first question, he noted that the participants had done a good job of responding to the second question. A number of new concepts had been put forward by the breakout groups. These concepts covered the full range of near term and long term ideas applicable to both noise and emissions environmental impacts. Reiterating the points made by those summarizing the accomplishments of the breakout groups, he emphasized that more work needed to be done to define specific goals for both noise and emissions and that some process needed to be put in place to generate and evaluate more technology options.

Regarding strawman roadmaps, NASA now had the task of developing figures of merit and conducting a cost benefit analysis to evaluate the proposals generated by the workshop. This would facilitate examining the technology options in terms of the Gap Analysis and assessing their potential contribution toward meeting the goals.

Returning to the first question, Mr. Murray noted that the participants had the assignment of talking with their constituents about the proposals placed on the table at the workshop. Do these concepts and ideas meet the needs of their organizations and constituents? Are these types of research and development programs important to aviation and the environment? At the next workshop the participants would be asked to share those views with their fellow workshop participants.

Frank thanked the participants for their hard work and their thoughtful contributions to the success of Workshop II and turned the meeting over to Howard for his closing thoughts.

Howard provided the final statements for the Workshop.

> Well, here we are again at the end of another hectic but hopefully productive planning exercise. As an engineer, I still prefer doing things rather than planning, but, as a NASA headquarters employee, I do recognize the importance of good planning, as painful as the experience might be.
>
> On Tuesday, I suggested that I'd return to the four questions, which were originally posed at Workshop I in Atlanta. Frank Murray has referred to these questions as "signposts," and indicated that we probably won't fully answer them during these workshops. But it may be good to look at the "signposts" to see how far we've progressed on our journey.
>
> 1. What are the impacts of aviation noise and emissions on the environment?
>
> 2. How do you believe those impacts may affect the growth of aviation?
>
> 3. Must the growth of aviation lead to increased environmental impact?
>
> 4. What is the relationship of NASA's noise and emissions goals to aviation's impact on the environment?
>
> Let me take a shot at the individual questions and suggest what we've done to provide answers. And this is another attempt to stimulate discussion, so I will not be offended if you have a different perspective. What's important is that we keep talking and seek consensus. So here's my spin on question #1.

1. What are the impacts of aviation noise and emissions on the environment?

We've attempted to address this question with various scenarios for aviation's growth. You've had an opportunity to discuss those scenarios during yesterday's breakout sessions. And I hope this morning's reports reacted to any concerns about related matters such as plausibility or aggressiveness. We'll open discussion again in a few minutes for additional comments.

2. How do you believe those impacts may affect the growth of aviation?

Nobody has yet expressed a belief that aviation's growth should stop. But the possible degree of noise and emissions mitigation certainly has a wide range.

NASA technologists and others will continue to offer projections, as we've done here, about how we might help. However, before authoritative guidance is offered in return, national and international policy makers will be required to assimilate that information and a lot of other considerations.

Therefore, it's been good to have the participation of the White House, the EPA and FAA in these workshops. And I know that these organizations are consulting with all interested parties - particularly those also here who are responsible for manufacturing and operating aircraft and those representing the public interest in a clean and quiet environment.

So I look forward to the evolving state of affairs, realizing that some ambiguity will likely remain. Although, as a concerned citizen and taxpayer, I hope that decisions will be based on sound principles similar to those used by the International Civil Aviation Organization:

- Scientific assessment of need.
- Technical feasibility.
- Economic reasonableness.

3. Must the growth of aviation lead to increased environmental impact?

As noted in Atlanta, this may be the key question. In the short to medium term, the scenarios seem to indicate that aircraft noise and emissions are likely to increase, even with application of new technology. Although the increase in noise will only occur with growth after the initial phase in of Stage 3 aircraft. In the far term, it appears that a combination of technology and operational measures can bring noise levels back to the early levels of the coming Stage 3 era, and maybe even reduce average community exposure.

For emissions, the situation is less certain. For as long as we keep using carbon-based fuels, it certainly appears that some increase in CO2 is inevitable, again even with new technology. And almost any alternative fuel still has NOx, H2O and cloudiness concerns. But significant improvements in fuel efficiency are possible, and should mitigate the increases in CO2 from the likely kerosene powered aircraft during the next few decades. Advanced combustor technology also promises significant reductions in NOx, which is both a local and global concern. Other fuels are not likely for a long time, but should continue to be studied along with alternatives for the gas turbine engine.

But the most likely "bottom line" seems to be that aviation's current small contribution to degradation of local air quality and global climate change may indeed grow some in the near and

even far term because technology and operational measures can not keep up with growth in demand.

I'm sure that's an uncomfortable message for almost everybody, and the issue will likely be debated for some time by policy makers. However, as a technologist, I see an opportunity here, and maybe we will do better than the present fuzzy future appears. I'd like to think the size of the NASA budget has some role in how well we might do, although invention does not always correlate with budget.

4. What is the relationship of NASA's noise and emissions goals to aviation's impact on the environment?

Obviously my NASA colleagues and I hope that the "Three Pillar" goals for reduction of noise and emissions fully address everybody's concerns about aviation's future environmental impact. But, as I indicated at Workshop I, "the goals were originally articulated in a purposely 'dramatic' although somewhat ambiguous manner for Administrator Goldin's overarching message, while allowing later development of appropriately more clear definitions for each of the specific enabling technology areas."

And that's where we are today, still trying to develop the original goals. I believe that you've helped us during the last two and a half days to more fully understand what may be appropriate objectives for mitigating aviation's environmental impacts. Our response is in the gap analyses and roadmaps that we introduced here, and these will be further developed with the information we've received from you and others.

These are my personal reactions to where we've been. I'll now turn the mic back over to Frank and look forward to your comments.

Adjourn Workshop

The Chairman adjourned the Workshop, thanking all for their participation.

****

NOTE: Comments from Rich Kassel, NRDC

Rich Kassel of the Natural Resources Defense Council was not able to attend Workshop II because of a previous commitment. However, he did have some comments that he wished to share with the participants regarding the three questions that were posed to the second workshop. His comments are provided below.

Regarding your "three additional questions", I'd briefly suggest the following:

Question #1: Have the needs been met?

I don't think the "customer" needs have been met, mostly because I don't think it's clear who the "customer" is. Traditionally, we have felt that FAA treats the airline and aviation industries as its "customer," which may be expeditious for the agency, but with unnecessary environmental and community impacts. Some might argue that the passenger is the "customer", but I'd respond that the passenger is the customer of the airlines, but not of the government agencies that are charged with regulating, planning, and mitigating the impacts for a broader population. In sum, I'd suggest that NASA's customer is that broader, general public, i.e., that you (together with FAA, EPA, DOE and other public agencies with responsibilities in this area) have been charged with developing strategies to meet the environmental and public health needs of the general public.

Certainly, the airlines, the passengers, the other aviation industry sectors each play a role, but I'd argue that it's only an implementation role. Here's an analogy that illustrates this point: the Clean Air Act directs EPA to set national ambient air quality standards based on what's necessary to protect public health and welfare; then states develop implementation plans to meet those standards in the most cost-effective manner, taking into account local conditions and the needs of many local interested parties. In the aviation setting, NASA's goals should be based on the public health and welfare needs (e.g., noise, VOC, NOx, PM and greenhouse gas emissions); then FAA, EPA and industry initiatives can determine the most cost-effective best way to meet those needs.

If you agree with this illustration, it is easy to see that the "customers' needs" have not been met. True, there has been some progress in quieter, cleaner and more efficient aircraft. However, growing air travel offsets much of this progress. NASA's challenge in the coming years will be to determine the environmental needs of the public; then, the agencies, the industry and the public will have to work together to insure that new technologies, operating systems and other mechanisms are in place to ensure that the public's two great needs (i.e., more mobility and more environmental protection) are met in the most cost-effective manner.

Questions #2 and #3: Have new concepts been put forward? Have recommendations for strawman roadmaps been developed?

All concepts (R & D, commercialization of new technologies; incentives for cleaner, quieter and more efficient operational systems, improved public policies) should be addressed. I wouldn't take any tool off the table at this point. But, I think NASA's role should be to help set the goals, to conduct the R & D; to create demonstration projects to test the new technologies, and to work with the various interested parties to move promising technologies to commercialization. Other policy instruments (incentives, for example) may be better left to agencies like FAA, EPA and DOE.

Thanks for the opportunity to participate in this limited fashion. Again, I'm sorry that my schedule does not permit me to spend three days with you this week. I am happy to review the SAIC staff summary, and to continue to participate in this process in the future.

Environmental Compatibility
Workshop III
Summary Report

The third Environmental Compatibility Assessment workshop met in Monterey, California on July 7-9, 1998. At the first workshop in Atlanta the participants focussed on defining the impact that aviation had on the environment. In the second workshop in Cleveland technology concepts were proposed for addressing these impacts. The theme for this the third and final workshop was "feedback". During the first day and one-half of this workshop, NASA responded to the suggestions for new concepts that had been proposed by the workshop participants in the second workshop. In their response NASA provided an overview of the current planning process including the latest look at the summary level "roadmaps". Then through a series of briefings and presentations the participants were provided additional information on the concepts that appeared to be most promising. During the last day of this workshop the roles were reversed and the participants responded with their feedback to NASA in the opinions and comments they provided to four general questions. This summary provides an overview of the major points of these responses and a synopsis of other workshop activities.

In this workshop's opening session NASA provided an overview of their planning and budget processes. This helped to provide an understanding of the major steps used by NASA management to review and make decisions regarding the research and technology proposals. During this overview it was noted that the time frame for the Three Pillar Goals had been changed from their original 10 year and 20 year targets to 10 year and 25 year targets. This places them in step with agency-level NASA strategic plan.

After this background, summary roadmaps for noise and emissions research and technology development programs were presented. The roadmap is the principal planning tool used by NASA in their program management for research and development programs. Each of the roadmaps identified the major recommended activities for noise and emissions research and the contribution, in terms of reduced noise and emissions, that each was expected to make to achieve the Three Pillar goals. The achievements in these program areas were also cast in terms of the time frame within which these reductions were projected to occur.

Following the NASA presentations a briefing was provided on the Los Angeles International Airport (LAX) and the difficulties it is currently facing in attempting to expand its operations to accommodate the rapid growth in passenger and airfreight traffic. LAX has a significant impact on the economic vitality of the region, and according to those providing the presentation, is the largest and fastest growing airport in the nation in terms of the value of imports and exports. Growth of the airport was described as essential to the continued growth of the regional economy. Both noise and emissions problems were listed as potentially key issues when the plans are presented for public review prior to the granting of the necessary approvals. The presentation pointed out the need for environmentally friendly technologies and the need to build better models and other tools to assess the impact of airport growth on the surrounding communities in terms of additional noise and emissions. The LAX officials emphasized that noise and emissions problems were not 10 or 20 years away; they are problems that many airports will be facing in the very near future.

Continuing the feedback theme, the participants then met in their noise and emission breakout groups for a series of presentations and discussions of specific technologies. These technologies had been proposed during the second workshop and the presentations provided additional information and a forum to raise questions and discuss these proposals in depth. The Emissions Breakout Group covered topics such as Zero Emissions Aircraft, Maximum Performance of Hydrocarbon Fuels, Alternative Fuels, Fuel Cells, and the DOE Hydrogen Program. The Noise Breakout Group heard presentations on Advanced Concepts, Distributed Exhaust, Active Noise, Airframe Noise, and Land Use Planning.

On the morning of the second day, the workshop reconvened in plenary session and interdependency briefings were provided on the relationship of other Three Pillar goals, e.g., safety, capacity, affordability, etc., to the environmental issues. Also operational technologies used to mitigate the impacts of noise and emissions were presented along with a briefing on the NASA Atmospheric Effects of Aviation Project. Finally, technology case histories were presented on the GE 90 Noise Study and the Dual Annular Combustor.

During the afternoon session the participants were organized into three groups. Each of the groups was composed of individuals associated with organizations that were believed to have similar concerns and interests. The groups included one for Operators which included both airline and airport operators; another was composed of participants from the Manufacturing Industry; and the final group was composed of the NGO, State and Local Government, and Community Representatives. Federal agency employees attending the meetings were free to observe any of these breakout groups. Each of the groups met separately and was asked to address four questions dealing with the Three Pillar Goals, Research Strategy, Roadmaps, and Moving Forward. The questions and highlights from the responses are provided below.

1) Will the attainment of the goals satisfy **your** environmental concerns?

The answers to this question varied from qualified yes to a qualified no. Key points included—

- The Three Pillar's goals were technology goals while the environmental concerns were the levels of emissions and noise from the fleet of operating aircraft;
- Other criteria (safety, affordability, etc.) had to be part of any solution before the technologies would be deployed, and
- The appropriateness of the goals was questioned, e.g., the use of a 20 decibel reduction for light aircraft, and differing interpretations of the emissions goals, e.g., emphasis on the landing and takeoff cycle for nitrogen oxides.

2) Does the NASA strategy appear to be appropriate?

While the responses generally indicated that the strategy was appropriate as far as it went, all three groups took the opportunity to provide additional comments some of these are provided below.

- The NASA strategy needed to address other types of aircraft;
- Funding needed to be available for development of promising technologies through Technology Readiness Level 6;
- Effective coordination between NASA research activities and that of other agencies, such as the Departments of Defense, Energy and Transportation and particularly with the Federal Aviation Administration, needed to be strengthened;
- The strategy needed to extend beyond the narrow confines of research and technology.
- Concurrent strategies for addressing market acceptance, certification, regulation, operations and other problems were necessary to achieve overall success.

3) Have the roadmaps reached appropriate near and far term balances? Leveraged other government and industry programs? Identified technologies to be pursued ASAP?

The groups felt that it was important to strike a balance between near term and far term programs with the near term focusing on carbon fuels.

- Short and intermediate term solutions were needed, improved aircraft and engine efficiency and better models were given special mention;
- Systems studies were important to evaluate the revolutionary concepts proposed for noise reduction;

- While technology is being developed, operational improvements (e.g., CNS/ATM), use of AST program technology development, and other measures (retrofits using current technology) need to be employed;
- 30 to 40 year goals for zero emission aircraft are important, but it should not be a tradeoff for near term goals;
- Alternative carbon based fuels were not viewed as being attractive, the opinion was that they had all the problems associated with building a new fuel infrastructure and few benefits; and
- Finally the role of NASA in far term research and technology development was viewed as crucial…"NASA has a critical role to play in a basic R & D program and in 'thinking outside the box!' "

4) What form of continuing communication with NASA would be of value? In what way would you be willing to participate in pursuit of these research objectives?

All of the groups expressed the view that continuing communication with NASA would be of value to their organizations and constituents and expressed a willingness to be actively involved in such an effort. Among the steps proposed for continuing communications were the following—

- Creation of a technical steering committee modeled after the AST Noise Reduction Steering Group.
- Expanding participation in meetings and workshops on environmental issues to include other relevant groups.
- Six-month reports on the progress of the research programs along with research test results and technical points of contact.
- Reports or articles understandable to the layman that can reach the broader community concerned about these issues, and
- Continuation of the ECoA website with expanded information and links to other relevant sites.

In response to the second part of the question the groups indicated their willingness to participate in the following ways—

- Participating in a broad information and education effort aimed at increasing public awareness and educating their constituencies.
- Providing forums for the discussion of the issues and the research activities at conventions, technical symposia and association meetings dealing with environmental issues.
- Use of airport facilities as test beds for development programs.
- Providing their time and expertise to review program proposals and providing NASA with an awareness of the concerns of their constituents, and
- Assisting in public communication and education of decision-makers.

NASA spokespersons expressed their appreciation to the participants for their hard work and contributions to the success of the workshops. They assured the participants that they would review their suggestions and comments carefully and would work with them to build and maintain the lines of communications for continuing the dialogue.

NASA ENVIRONMENTAL COMPATIBILITY RESEARCH WORKSHOP III
Monterey, CA
July 7 – 9, 1998

Agenda

Tuesday July 7, 1998

8:00 a.m.	Plenary – Welcome/Workshop Agenda/ Schedule and Logistics for Afternoon	Frank Murray
8:30 a.m.	Update on NASA Planning Process (Status report, Road maps, Gap analysis)	Howard Wesoky
	Noise Presentation	Dave Stephens
	Emissions Presentation	John Rohde
10:30 a.m.	Break	
10:45 a.m.	Los Angeles International Airport (LAX) Master Plan	Jack Graham
12:00 p.m.	Lunch	
1:00 p.m.	Convene Breakout Groups	

Noise Breakout Group	**Emissions Breakout Group**
· Existing NASA Program Overview (Bill Willshire) · Engine Noise ♦ Advanced Concepts (Ian Waitz) ♦ Distributed Exhaust (David Schein) ♦ Active Noise Control (Isam Yunis) · Airframe Noise (Belur Shivashankara) · Community Noise ♦ Active Control (Ben Sharp) ♦ Land Use Planning (Nick Miller)	· Existing NASA Program Overview (Russo/Rohde) · Max-performance for HC Fuels (Carol Quinn) · Zero Emission Aircraft (Chris Snyder) · JP/Alternative Fuels (Oren Hadaller) · DOE Hydrogen Program (Jim Ohi) · Fuel Cells (Tom Maloney) · Local Air Quality (Jack Graham)

2:30 p.m.	Break	
2:45 p.m.	Reconvene Breakout Groups	
4:30 p.m.	Adjourn/Reception	

Wednesday July 8, 1998

8:00 a.m.	Reconvene in Plenary	Frank Murray

8:05 a.m.	Interdependency	
	Three Pillars Goals	Bob Pearce
	Operational Technologies to Mitigate the Impacts of Noise and Emissions	John-Paul Clarke Tom Davis
	Atmospheric Science Topics	Don Anderson
10:30 a.m.	Break	
10:45 a.m.	Technology Readiness Case Studies	
	GE 90 Noise Study	Phil Gliebe
	Dual Annular Combustor: A Technology Readiness Case Study	Will Dodds
11:45 a.m.	Logistics for Afternoon – Interest Group Breakouts	Frank Murray

Revisiting the Original Four Questions:

- What are the impacts of aviation noise and emissions on the environment?
- How do you believe these may affect the growth of aviation?
- Must the growth of aviation lead to increased environmental impact?
- What is the relationship of NASA's noise and emissions goals to aviation's impact on the environment?

12:15 p.m.	Lunch	
1:15 p.m.	Feedback	

Three groups will be organized:

- Industry — Bob Cuthbertson
- NGO/Communities — Betty Ann Kane
- Operators — Ray Brown

The groups will be asked to address the questions provided below and to report back to the Workshop on Thursday morning:

1. Goals:

   · Will the attainment of the goals satisfy ***your*** environmental concerns?

2. Research Strategy:

   · Does the NASA strategy appear to be appropriate?

3. Road Maps:

   · Have the Road Maps reached an appropriate balance between near term and far term goals?
   · Have the Roadmaps properly leveraged other government and industry programs?
   · What technologies need to be pursued as soon as possible?

4. Moving Forward:

   · What form of continuing communication with NASA would be of value to your organization?
   · In what way would you be willing to participate in the pursuit of these research objectives?

5:00 p.m.	Adjourn	
Thursday July 9, 1998		
8:00 a.m.	Plenary Meeting Report of the Feedback Groups; discussion	
10:00 a.m.	Break	
10:15 a.m.	Continue the Reports and Discussion	
11:00 a.m.	Impressions and Observations	Cindy Newberg Don Sutkus
11:15 a.m.	Closing Comments	Frank Murray Howard Wesoky
12:00 p.m.	Adjourn	

Minutes of the NASA Environmental Compatibility Research Workshop
Held July 7-9, 1998
At The Monterey Plaza Hotel, Monterey, CA

The following persons attended this Workshop.

First	Last Name	Company
Krish	Ahuja	Georgia Institute of Technology
Richard	Altman	Pratt & Whitney
Donald	Anderson	NASA Goddard
Richard	Antcliff	NASA Langley
Chris	Arman	City of Chicago/O'Hare Airport
Howard	Aylesworth	Aerospace Industries Association
David	Bowles	NASA Langley
Gerald	Brines	Allison Engine Company
Ray	Brown	Delta Airlines
Lisa	Chang	EPA
Adina	Cherry	SAIC
Kestutis	Civinskas	NASA Lewis
John-Paul	Clarke	MIT
Thomas	Connor	FAA
Charles	Cowan	Cutler & Stanfield
Robert	Cuthbertson	The Boeing Company
Thomas	Davis	NASA Ames
Ruben	DelRosario	NASA Lewis
Dallas	Denery	NASA Ames
Barbara	Dillon	SAIC
Willard	Dodds	GE Aircraft Engines
John	Dodge	AlliedSignal
Sam	Dollyhigh	NASA Langley
Michael	Dudley	NASA Ames
Doug	Dwoyer	NASA Langley
Dick	Dyer	CA DOT
Tony	Fiorentino	Pratt & Whitney
Phil	Fowlie	United Airlines
Don	Galbraith	Galbraith Associates
Jarvis	Gantt	Univ. of TX-Applied Research Labs
Christine	Gerencher	Landrum & Brown
Glenn	Gilyard	NASA Dryden
Philip	Gliebe	GE Aircraft Engines
John	Graham	Los Angeles International Airport
Oren	Hadaller	The Boeing Company
William	Haller	NASA Lewis
Peter	Hart	Allison Engine Company
Robert	Howard	AEDC/Sverdrup
Aubre	Howell	Northrop Grumman
Jim	Humphries	Sacramento International Airport
Lynae	Jacobson	SEATAC Airport

Rod	Jago	SAIC
Betty Ann	Kane	National Org. to Insure Sound Environment
Rich	Kassel	National Resources Defense Council
Barry	Kiel	AFRL/PRTC
David	Koert	Wichita State U.-National Institute of Aviation Rsch
Richard	Lawrence	NASA Goddard
Duc	Le	US DOE
Ellina	Levina	Center for Clean Air Policy
Anita	Liang	NASA Lewis
Dick	Linn	Dallas-Ft. Worth Airport
James	Littleton	FAA
Gary	Machles	GE Aircraft Engines
Tom	Maloney	Dunacs/NASA Lewis
Bill	Marx	FAA
Doug	Mathews	Pratt & Whitney
Peter	McCallum	NASA HQ
Richard	Miake-Lye	Aerodyne Research Inc.
Nicholas	Miller	Harris, Miller, Miller & Hanson
John	Morgenstern	Lockheed Martin
Louise	Mudd	FAA/TRW
Frank	Murray	SAIC Consultant
Kevin	Nesbitt	CALSTART
Cindy	Newberg	EPA
Jim	Ohi	National Renewable Energy Lab
Charlie	Parente	Northrop Grumman
John	Pehrson	Camp Dresser & McKee Inc
David	Picasso	NASA Ames
Clemans	Powell	NASA Langley
Carol	Quinn	NASA Lewis
Ron	Ray	NASA Dryden
Lisa	Reuss	SAIC
Karen	Robertson	Dallas-Ft. Worth Airport
John	Rohde	NASA Lewis
Carol	Russo	NASA Lewis
Naseem	Saiyed	NASA Lewis
David	Schein	Northrop Grumman
Arun	Sehra	NASA Lewis
Fredric	Schmitz	Univ. of Maryland
Paul	Senick	NASA Lewis
Ben	Sharp	Wyle Laboratories
Belur	Shivashankara	The Boeing Company
Brian	Smith	NASA Ames
Chuck	Smith	NASA Ames
Glenn	Smith	NASA HQ
Chris	Snyder	NASA Lewis
David	Stephens	NASA Langley
Gary	Stowell	San Jose International Airport

Don	Sutkus	The Boeing Company
Mary	Vigilante	Synergy Consultants, Inc.
Ian	Waitz	MIT
Donald	Weir	AlliedSignal
Howard	Wesoky	NASA HQ
Chowen	Wey	NASA Lewis
Bill	Willshire	NASA Langley
Keith	Wilschetz	Landrum & Brown
Ted	Woosley	Landrum & Brown
Jia	Yu	BFGoodrich Aerospace
Isam	Yunis	NASA Lewis
Rick	Zelenka	NASA Ames

Welcome and Introductions
Schedule and Logistics
Agenda for Workshop III

Frank Murray opened the meeting by welcoming all attendees and mentioning that the major theme of this Workshop was "Feedback." He reviewed the Workshop agenda and the process to be followed at this meeting. He mentioned that the three "Interest" groups, Industry, Operators, and NGO/Communities would be meeting Wednesday to begin the "Feedback" report. Frank briefly reviewed the four questions each group was scheduled to address. (These questions are included in the agenda). He stressed that serious consideration should be given to the question of the continuing dialogue to ensure that the recommendations coming from the workshops are not forgotten after the workshop process is completed. He reviewed changes to the agenda, meeting logistics, and other general housekeeping functions then turned the meeting over to Howard Wesoky.

Update on NASA Planning Process

Howard discussed the history of the ECoA Team and charter and the motivations for its creation. White House Policy, the European Commission, the Kyoto Protocol, and the "Three Pillars" Goals, specifically the goals for reduction in aircraft noise and emissions were also discussed. He stated that the three-workshop process was designed to bring NASA together with industry, universities, government agencies, and non-governmental organizations in order to accomplish the goals mandated by NASA. He also stated that not all environmental goals have purely technical or engineering solutions, and that strategies such as pollution credits should not be discounted. Howard discussed the Aeronautics and Space Transportation Technology Advisory Committee (ASTTAC) and its members, as well as the workshop process and objectives. He summarized that there is a strong mandate for NASA to initiate significant investment toward the "Three Pillars" emissions and noise goals. As a result of NASA's mandate, fulfillment of the Three Pillars goals became the workshop objective. Howard then introduced Dave Stephens to brief the participants on what the Noise research program was accomplishing.

Please note, copies of the briefings summarized in these Minutes are available on the ECoA website at http://www.hq.nasa.gov/office/aero/oastthp/programs/encompat/encompat.htm.

Noise Environment

Dave Stephens presented the noise perspective. He briefly reviewed the Pillar Goals with the Workshop attendees and the timing associated with attaining the goals. He reviewed the benefits associated with achieving the goals from the perspective of a single event noise level and from a community noise exposure event. The benefits resulting include the following: 1) aircraft noise would be confined within airport boundaries; 2) the environment would be curfew-free with unconstrained operations and growth; and 3) the US would realize improved competitiveness. Dave then reviewed the Gap Analysis requirements, areas of concentration, and potential contributions. The four principal elements, engine systems, airframe systems, modeling and integration, and airspace operation, as well as the corresponding reduction goals of the environment program were briefly discussed. He then presented the ECoA strategy with related needs, concepts, and goals and resulting Roadmaps developed to achieve them. The Roadmaps and charts of Dave's presentation can be found on the NASA ECoA website under the Monterey Workshop III.

Emissions Environment

John Rohde updated the group on the emissions perspective. His presentation included CO_2 and NO_x reduction waterfalls with AST technologies, ECoA initiatives and notional concepts. He also discussed zero-emissions 777-type aircraft, fuel cell/electric motor/ mini-fan propulsion systems, and revolutionary concepts for both carbon- and non-carbon-based fuel systems. Roadmaps were presented which included goals for 10, 25, and 30-40 years. The technology challenges in achieving the goals were then identified for the group. John then reviewed potential level 2 plans for propulsion, airframe, and ground and flight operations, which supported achievement of the goals. The impacts of emissions metrics definition were also discussed. John's briefing can be found on the NASA ECoA website.

Los Angeles International Airport (LAX) Master Plan

Jack Graham led the discussion on the LAX master plan with the assistance of Keith Wilschetz and John Pehrson. Although the LAX Master Plan is still in development, it provides a sound technical basis for addressing a variety of issues associated with airport growth. The issues discussed during the presentation include the regional economic importance of LAX, LAX activity levels, local air quality, and LAX's national importance. Graham stated that LAX is the busiest cargo and passenger link to Asia in the continental US, and is vital to California's economy. Over the past several years, passenger demand has increased by 10 million people, and cargo tonnage increased by 24 percent. Further increases are predicted for the near future. Resulting unrestrained growth would have a significant impact on not only the environment, but also on automobile and traffic congestion in the vicinity of the airport, as well as increasing passenger activity that will result in displacement of connecting passengers. The LAX Master plan provides for planned orderly growth; minimization of adverse environmental impacts; improved airport efficiency; and enhanced land use compatibility with the adjacent communities. The LAX Master plan will analyze air quality impacts associated with aircraft, ground support equipment, stationary facilities, motor vehicles, and construction equipment, and attempts to minimize the environmental impacts of emissions. Jack also stated that while other area airports will need to be expanded to meet the anticipated increase in passenger demand and cargo shipments, there are no plans to build a new airport. He also stated that many other airports face the same problems and concerns regarding expansions and growth as LAX, but do not publicly voice these concerns to avoid being highlighted. In closing he stated that it is imperative that these problems be addressed to ensure that air quality regulations do not effectively handicap the airport plans to meet increasing passenger and cargo demands.

Further discussion among the participants resulted in variety of questions. It was mentioned that while there are no hard numbers on the impacts of LAX on Los Angeles air quality, in the Los Angeles basin,

aircraft are responsible for approximately 10%, while in the vicinity of the airport the number can be as high as 50%. The master plan also calls for minimization of vehicle usage on the airport, and for transportation to the airport. Dick Linn inquired as to the plans for subway or metro system to the airport. The Master Plan calls for a metro link to the airport. The issue of noise impact on the surrounding community was also mentioned. The master plan does take noise into consideration by calling for runways to be set so that noise contours are more advantageously situated.

Following the LAX briefing, the noise and emissions breakout groups formed for a series of presentations and discussions.

Breakouts

Noise Breakout Group

Bill Willshire opened the Noise Breakout session with an overview of the NASA Noise-related Programs.

Existing NASA Program Overview

Bill provided a thorough overview of noise technologies, in relation to the Advanced Subsonic Technology Noise Reduction Program. He began by showing that the program drivers were integrated, including environmental concerns, enhanced marketability, and increased capacity. Bill reviewed the Level I Roadmap and milestones and noted the sub-elements of the program—engine noise reduction, interior noise reduction, airframe noise reduction, nacelle aeroacoustics, and community noise impacts. An important aspect of the program is that a successful steering committee and technical working group were both formed to involve industry in program planning. He covered some of the tests involved in noise reduction like the fan broadband noise test and the low turbulence pressure tunnel high-lift airframe noise experiment. He discussed some of the technologies being utilized for noise reduction, such as computational fluid dynamics for airframe analysis; and microphone arrays for measurement of noise. Bill concluded that the AST program is a result of an extensive NASA inter-center, FAA, and industry partnership and that it has reached its interim objectives and is now reaching further. Bill's entire presentation is contained on the NASA ECoA website.

Advanced Propulsion Concepts (Selected)

Ian Waitz of MIT presented selected Concepts of Advanced Propulsion, beginning with an overview of the current opportunities for improvement in this area. The areas that can be improved include materials for greater durability, strength/weight ratios, new and better thermodynamic cycles, new and better engine architectures, and utilization of different or non-hydrocarbon based fuels. One of the concepts of advanced propulsion he mentioned was aspirated counter-rotating compressors. Some of the advantages of this turbofan include much lower production cost, lower fuel burn, shorter engine, lower engine weight, and low noise. The other area of advanced propulsion is in micro-scale opportunities and in micro electric mechanical systems (MEMS). Ian stated that although there is currently no working engine, MEMS-based thermal engines appear both promising and useful. There are potential applications in propulsion, power generation, and microrocket engines, among other areas. In closing, he stated that the further development of MEMS technology presented many challenges and opportunities, and that there was a high risk coupled with a big reward.

Active Noise Control Vision: 2007-2022

Isam Yunis, NASA Lewis, briefed the Noise Group on the Active Noise Control (ANC) reality based goals and status of those goals. He discussed different methods of ANC like active engine walls and

active actuators along engine walls and stators. Isam listed some of the technologies to achieve those goals like smart materials and jet instability wave control and concluded with the visions for both 2007 and 2022.

Airframe Noise Sources

Belur Shivashankara of Boeing spoke about the major sources of noise found on airframes. The leading edge, flap edge, landing gear, and the interaction of the jet flap are the leading contributors of airframe noise. Any increase in the size of the wing results in an increase in the noise level of the airframe during approach and landing. He mentioned that Boeing conducted extensive tests in 1992-93 to determine the major contributors to airframe noise. Now that they have identified these sources, work has begun on developing suppression techniques. He noted that Boeing believes that you can reduce airframe noise by approximately 2 or 3 dB, perhaps more. In closing, he stated that there is still more work that needs to be done to determine the most effective methods of noise suppression for airframes. The slides shown during the presentation contain information proprietary to Boeing, and will not be posted on the website.

Active Control of Aircraft Noise in the Community

Ben Sharp of Wyle Laboratories presented his work in active noise. Ben began his presentation by stating that low-frequency noise from ground run-up operations is a major source of community annoyance. This occurs most commonly at night, when the majority of maintenance work takes place. The current solution, 'hush-houses' are expensive and inconvenient, and are not suited to airports with only localized problems. He stated that Active Noise Control (ANC) is based on the interference that occurs when two coherent sound waves are combined. This is achieved by means of a secondary noise source that is used to generate sound in anti-phase to that which is created by the unwanted noise. This results in an overall reduction in the noise level. ANC is an available solution to the noise reduction problem. ANC can be used either for global noise reduction by placing the control source near the source of the unwanted noise, or for local control by placing the control source at a distance from the aircraft in a location where noise levels are lower and can be easily generated by artificial sources. Test results indicate that the system does work—a reduction of 5-10 dB has been achieved in an area of over 5000 sq. meters. A fully functioning prototype will be available by Fall 1998 for demonstrations.

Aircraft Noise and Land Use Planning

Nick Miller discussed Aircraft Noise and Land Use Planning. He began by stating that there are two basic dimensions to the issue: political – what the communities perceive to be true with regard to noise; and technical – the analytical facts of aircraft noise. He stated that there is a divergence between what the communities and the airports/FAA perceive regarding aircraft noise. He then questioned whether the airports and FAA understand the problem. Do they know where the aircraft fly, what noise levels they produce, or when the 'impact' of the noise occurs? He stated that since noise contours summarize the extent of our knowledge about noise levels and impacts, it is very important that they be accurate. Because of this, Nick felt that we need to improve our modeling capabilities. This led to a group discussion on how the contour tools can be used to better understand the problem, and how to interface with the communities experiencing problems with aircraft noise.

Emissions Breakout Group

John Rohde opened the session with an overview of NASA's current emissions' programs.

Existing NASA Program Overview

John reviewed the current NASA programs by briefing the Level 1 Roadmap and the emissions reduction waterfalls. He proceeded through some scenario-based vehicle technologies and noted the fuel burn reduction by area of technology: aerodynamics, structures, propulsion, and systems. John went through similar process for the emissions (both for CO_2 and NO_x) reduction waterfalls and the effect of technology. He showed the impact of technology on future emissions, the best resulting from the AST Program plus base NASA technology. John discussed engine, airframe, and materials technologies, which might be applied, as well as possible alternative fuels and physics and process modeling.

When asked about the extent of the synergy or discrepancies between noise and emissions goals/roadmaps, it was stated that there are no major disconnects. Although the research for the technologies differs to some extent in that the airframe/wing efficiencies differ for noise and emissions, the main purpose is still to maintain clean engine flow. John also stated that future programs would consider aerosols for emissions, and that NASA is attempting future programs dealing with the environment as well as economics.

Max CO_2 Reduction of Kerosene Fueled Turbofan Aircraft

Carol Quinn presented the results of the study determining the "ultimate" CO_2 reduction possible for a conventional subsonic transport with turbofans. She discussed how performance was pushed "to the limit" of what is theoretically possible for a turbofan engine. Carol then showed CO_2 waterfalls for the 3 different scenarios that she studied; 100 passenger (pax) aircraft, 325 pax and 800 pax, and subsequently demonstrated that with kerosene fuel, the maximum possible reduction in CO_2 would be approximately 82%, which included not only engine, but also airframe improvements. Carol concluded that the maximum *practical* emissions reductions for the 3 scenarios were 50%, 58%, and 65%, respectively.

Scenarios for Aviation's Growth: Opportunities for Advanced Technology: "Zero-Emission" Aircraft

Chris Snyder discussed the study of zero-emissions aircraft. He gave the parameters and baseline aircraft used for the study and the fuel concepts included to achieve zero emissions. The fuels were hydrogen, methane, nuclear power, and fuel-cell electric power. He did NOT study battery power due to previous studies, which have found batteries to be extremely heavy for take-off. Chris discussed the above fuels in detail, stating the considerations, then provided a summarization of the results. He said that he would do future research in the area of fuel cells as he saw this as the most feasible option in alternative fuels unless safety was eliminated as an issue for nuclear power.

The issue of using hydrogen as a fuel cell was mentioned. Several people pointed out that there are storage difficulties associated with hydrogen—it would require an extremely large fuselage. When asked about the trade-off with other emissions such as Methane and H_20, Chris stated that since CO_2 and NO_x are currently the biggest concern, that would remain the primary focus. Solar and nuclear fuels were also examined, but solar creates problems during night flying, and nuclear has issues associated with safety and weight requirements. Other hydrocarbon-based fuels are similar to current fuels, so they don't offer much hope for any emissions advantages.

Minimizing the Environmental Footprint of Commercial Aviation

Oren Hadaller gave a presentation on minimizing the environmental footprint of commercial aviation. He talked about the abundance of coal/natural gas in the world and noted that there should be no concern as to the availability of aviation fuel in one form or another. He basically agreed with Chris' discussion on alternative fuels, went through some statistics and concluded that more studies should be done with

synthetic kerosene, nuclear, hydrogen, and chemical fuel cells (electric). He also concluded that there are adequate petroleum-based fuel resources for aviation, which include synthetic jet fuel. He stated that improved efficiency would minimize the environmental footprint of aviation. Oren made a point to say that alternative fuels for aviation must be evaluated based on 'resource through end use', not just initial usage in order to evaluate aircraft fuel correctly.

US DOE Hydrogen R&D Program

Jim Ohi said that the Department of Energy Hydrogen Program conducts applied R&D in hydrogen production, storage, and utilization to enable hydrogen to be a cost-effective energy carrier for utility, building, and transportation applications. He discussed recent world trends and multisector activities, as well as some of the accomplishments for the year 1997, including development of Magnesium/Zinc/ Aluminum alloys with properties attractive for vehicle applications and analysis of the cryogenic pressure vessel concept. Jim briefed some of the R&D highlights and then some planned 1998 activities. He also discussed the use of hydrogen for subsonic flight, and the preparation of airport scenarios, systems analyses, and action-plan development. Jim concluded his presentation by discussing the possibility of a joint venture with NASA.

Fuel Cell Propulsion for Commercial Aircraft

Tom Maloney began his presentation of fuel cells by discussing the various types of fuel cells, which include Proton Exchange Membrane (PEM) Acid Electrolyte and solid oxide electrolyte fuel cells (SOFC). Tom then discussed fuels compatibility, as well as some general considerations of fuel cells. He also stated that while hydrocarbon fuels are still the most practical, pollution could only be reduced, not eliminated. Tom also discussed the various applications for fuel cells, as well as current development efforts. He discussed the various companies and agencies involved in fuel cell development for areas such as space vehicles (i.e. Gemini and Apollo), and those used in buses. Tom then reviewed the technology status of various designs of solid oxide fuel cells. He stated that for aircraft propulsion, PEM would be available earlier than SOFC, although SOFC's are better suited to heavy hydrocarbon fuels than PEM. In closing, he stated that the design and testing of fuel cell systems for commercial aircraft is constrained by time and money, and that full system flight tests are not realistic near-term goals. He emphasized the need to conduct technical and life cycle cost analyses to determine the feasibility of fuel cells, and the need to conduct design and verification tests to answer key questions regarding performance.

Wednesday, July 8, 1998

Frank reconvened the workshop by reviewing the agenda for the second day's activities.

Interdependency Three Pillar Goals

Howard Wesoky spoke once more about NASA's "Three Pillars," but now added that 8 out of the 10 goals were, in fact, interdependent. He noted that aircraft demand was increasing, as shown by both Boeing and AIA estimates, and that this would have an impact on noise and emissions if nothing were done. Howard discussed the benefits of some of the other goals. He mentioned that the safety goals, if achieved, would save lives and how CNS/ATM would reduce noise and emissions if done efficiently. Other goals were discussed with their resulting interdependencies. He then discussed the NASA noise and emissions roadmaps in general terms. He noted that 2007 and 2022 would require evolutionary and revolutionary technologies respectively. Howard concluded that the goals are interdependent and that it was important for the participants to realize that even if one specific item was not being covered under the noise and emissions goals that it was most likely being covered under another goal.

Operational Technologies to Mitigate the Impacts of Noise & Emissions

John-Paul Clarke of MIT began this presentation by saying that he and Tom Davis would be sharing the responsibility of briefing. He would be describing the interplay of aviation operations and environmental impact and Tom would be introducing aviation operation decision support tools, which incorporate noise and emissions constraints.

John-Paul discussed the motivations for changing aviation operations to assist the environment. One motivation is that noise is an important factor in the siting and operation of airports. A second is that the noise problem is not just national but global problem. A third is that engine technology has provided significant noise reductions already. A fourth is that operational procedures can provide significant additional noise reductions. John-Paul then presented a chart created by Boeing, which showed the reductions in aircraft noise from 1950 to present. He discussed more motivations, including the limitation by ground-based flight guidance technology and advanced flight guidance technologies, which can improve the applicability and effectiveness of noise abatement procedures. Further emissions-related inducements were presented. John-Paul discussed air traffic control (ATC) and how it could affect emissions of aircraft, indicating that: 1) Airports affect local air quality; 2) Improved operational procedures are gaining importance as means of reducing emissions; and 3) surface and terminal area operations are a primary source of aviation-based ozone creating emissions in lower atmosphere. He stated that minimizing delays and inefficiencies would reduce emissions and constraints on growth of aviation. He felt that automation was required and that creative design for ATC was critical for success. He mentioned systems such as Center TRACON Automation System (CTAS), Final Approach Spacing Tool (FAST), Surface Movement Advisor (SMA), and Expedite Departure Planner (EDP) as possible applicable systems

Tom Davis then proceeded to brief specifically on the histories and benefits of the systems John-Paul previously addressed. He concluded that advanced aviation operations technologies can play a major role in diminishing environmental impact by using advanced decision support tools to enable system users to efficiently and effectively operate, subject to noise and emission constraints; and advanced flight guidance technologies to enable all vehicle classes to operate efficiently while minimizing noise and emission impact.

During the ensuing discussion, John-Paul indicated that they had interviewed pilots during the design of their model, and that the values they used were predicted values obtained from Boeing. He also stated that although they used predicted values, they were about as accurate as ones that could be obtained by measurements. Tom stated that while Turn Advisory and FAST are available, they are not currently in use by ATC. He also mentioned that while weighting factors are incorporated in real time, there are still some unresolved issues with it.

Atmospherics Science

Don Anderson discussed the assessment of atmospheric effects of aviation. His objective was to provide a scientific basis for assessment of atmospheric impact of supersonic and subsonic aviation, particularly commercial aircraft cruise emissions. His approach was to coordinate the program of aeronautical research to characterize engine emissions and their dispersal from aircraft and atmospheric science research to evaluate effects of aircraft emissions. Don introduced the Steering Committee Charter between NASA, NOAA, and the EPA and mentioned several of the collaborations and agreements with universities in support of the program.

The GE90: A Case Study

Phillip Gliebe presented a case study on the development of quieter engines through leveraging NASA technologies. He began by stating that the GE 90 is the engine used on the Boeing 777, and represents the application of proven technologies as well as demonstrating new technologies. The GE 90 is a member of the high bypass ratio engine family, which includes the CF6 and CFM56. The GE90 engine design and development was influenced by NASA's Quiet Engine Program in the 1960s, the Quiet, Clean, Short-Haul Experimental Engine Program (QCSEE) of the 1970s, and the Energy Efficient Engine Program and the Unducted Fan (UDF) Engine program of the 1980s. He stated that the key technologies utilized in the GE 90 as a result of these initiatives are the composite fan blade, dual annular combustor, and E^3 high-pressure compressor. Phil then discussed the key technologies in greater detail, as well as discussing recent progress in the reduction of engine noise utilizing the GE 90. He ended his briefing by summarizing the influence of NASA funded noise research on the GE 90 engine design, and stated that new and derivative product engines will also benefit from NASA funded technology. He also mentioned benefits of integrating academia into the partnership, as they contributed substantial theoretical research on the design of the GE 90, and that the synergy among NASA, industry, and academia often yields the best technological improvements.

The Dual Annular Combustor (DAC): A Technology Readiness Case Study

Will Dodds presented the case study on the dual annular combustor. He initiated his presentation by stating that the change to the dual annular combustor was based on a NASA technology program. He then described the process by which emissions such as NO_x, CO_2, water, and sulfur aerosols are formed, in order to explain how the design of this combustor reduces those emissions. Will then described the design of the combustor, and explained the history of its design, which dates back to the first DAC engine program, run by NASA in 1974-78. Will reviewed the factors that affected product transition, among them the fact that key technical issues were not addressed early enough in concept development. He also discussed the key factors that aided product transition. In closing he discussed the lessons learned from the DAC program. When asked why the dual annular combustor engine is not used more widely throughout the airline fleet, Ray Brown indicated that the increased maintenance of the DAC vice the single annular combustor, along with the lack of operational benefit, makes it a less attractive choice for airlines.

Logistics

Afternoon Breakouts

Howard Wesoky introduced this item by reviewing the questions formulated at the first workshop:

- What are the impacts of aviation noise and emissions on the environment?
- How do you believe these may affect the growth of aviation?
- Must the growth of aviation lead to increased environmental impact?
- What is the relationship of NASA's noise and emissions goals to aviation's impact on the environment?

He stated that many of the answers to these questions have been discussed during this and preceding workshops and that this Workshop would now look at the Three Pillar Goals, NASA's research strategy, its Roadmaps, and how to move forward. With that he turned the meeting over to Frank Murray.

Frank told the Group that they were now going to break into three subgroups and address the questions contained in the agenda for this portion of the Workshop and then report back to the plenary on Thursday

morning. He mentioned that Bob Cuthbertson would lead the Industry Group, Ray Brown, the Operator Group, and Betty Ann Kane, the NGO/Communities Group. He stressed that Federal employees could attend any of the sessions but only as observers and, if asked to leave at some point, they could enjoy the local Monterey area.

The three Breakout Groups met for the rest of the afternoon to formulate their answers to the following questions.

Goals

- Will the attainment of the goals satisfy your environmental concerns?

Research Strategy

- Does the NASA strategy appear to be appropriate?

Road Maps

- Have the Road Maps reached an appropriate balance between near term and far term goals?
- Have the Road Maps properly leveraged other government and industry programs?
- What technologies need to be pursued as soon as possible?

Moving Forward

- What form of continuing communication with NASA would be of value to your organization?
- In what way would you be willing to participate in the pursuit of these research objectives?

Frank also asked each of the Groups to consider what kinds of information would be of interest to them in regard to NASA feedback.

Thursday, July 9, 1998

Results of Breakouts

Plenary Meeting – Report of the Feedback Groups and Discussion

Beginning with the Industry Breakout Group, each of the breakout groups presented their reports to the entire workshop. These presentations are also available on the website. A summarization of the reports is provided below.

Goals

- *Will the attainment of the goals satisfy your environmental concerns?*

There seemed to be a consensus (2 out of 3) that YES, the attainment of the goals would satisfy environmental concerns, but there were qualifications to that question by all three groups. Industry said that affordability, safety, and emissions goals must be simultaneously addressed with noise. Operators said that there is a need for more short-term/intermediate goals/solutions. NGO/Communities questioned whether the measurement tools used were adequate for NO_x and thought that a clearer connection between NASA's research goals and the real-world impact was necessary to satisfy environmental concerns.

Research Strategy

- *Does the NASA strategy appear to be appropriate?*

Generally, all three groups felt that the NASA strategy appeared to be appropriate, however, there was some question during the breakouts as to what exactly NASA's strategy was. Industry assumed that the gap analysis defined the strategy and that system studies should guide revolutionary concepts for noise reduction. The operators felt that a better understanding/definition of emissions and criteria would help resolution as well as advocacy by interest groups for assisted funding. The NGO/Community group thought that NASA's strategy should parallel research for market acceptance. They thought that it was important that noise and emissions strategies were worked concurrently to cover all bases.

Road Maps

- *Have the Road Maps reached an appropriate balance between near term and far term goals?*

Industry felt that NASA needed to stress continuous parallel evolution of quieter components and airplanes. On emissions, industry thought that the near-term focus should be on carbon fuel. Operators thought that emissions should focus on more near-term work, within 5 years. They felt that noise was balanced appropriately. NGO/Community said that maybe 30-40 year goals should be added, but in addition to short-term goals, not in place of them.

- *Have the Road Maps properly leveraged other government and industry programs?*

Industry said that there was opportunity for excellent flow from the AST Program. There must be ties with aerodynamics, structures, CNS/ATM, etc, in the noise area. Emissions, they saw as leveraged well. Operators recognized a disconnect between emissions and noise with other activities like CNS/ATM. They thought that there should definitely be some obvious interdependency. NGO/Community group thought that NASA should take a lead in leveraging other government and industry programs, that they have the support of those present at the workshop.

- *What technologies need to be pursued as soon as possible?*

Industry saw that the roadmaps did an adequate job of defining those technologies that should be pursued as soon as possible. NASA just needs to follow that roadmap, keeping to the idea of improved efficiencies. Operators thought that local air quality modeling and improved noise models were a good investment. NGO/Community said that AST was an excellent program to model and that maybe dual annular combustors should be seriously considered.

Moving Forward

- *What form of continuing communication with NASA would be of value to your organization?*

Industry discussed how the AST Program was a good model to use for future programs. It provided a method for cooperation/coordination. Operators thought that a report every 6 months showing progress would be a good way to keep in touch with the program. The NGO/Community felt that two-way exchange of information and ideas would help as well as continuous update of the existing website.

- *In what way would you be willing to participate in the pursuit of these research objectives?*

Industry saw that forming a focus group and technical working group/steering committee would be one way to participate in pursuit of research objectives. Operators gave a list of way to participate including educational outreach, critiques, data providing, meetings, etc. NGO/Community was willing to provide opinions and review proposed programs, provide public awareness of related programs and help educate decision-makers.

Impressions & Observations

Cindy Newberg and Donald Sutkus were again asked to give their impressions of the workshop. Some of the lessons learned are listed below:

- The blending of presentations and discussion groups was effective, particularly in Cleveland.
- NASA was responsive to requests for supporting information (i.e. DOE hydrogen talk), particularly in Monterey.
- The off-site (from D.C.) locations were useful, and resulted limited distractions and neutral territory.
- Between the first and third workshop, NASA's role and participation increased greatly… to what extent was this a pro or con?
- A clear picture of the relationship of our work to other Pillar Goals work (i.e. HSCT connection) was lacking.
- The workshops were and excellent forum for building relationships with stakeholders in the noise/emissions field.
- Breakout groups by affiliation (I.e. NGO, industry,…) were effective but too late to allow adequate exchange of results.
- Should have had a non-NASA federal employee group and an academic group.

Don presented the outstanding issues:

- Three Pillar Goals are given in terms of implementation time frames … we need more discussion on this. He suggested Workshop IV in Hawaii.
- How far should TRL6 take you toward a finished product? Should NASA go further?
- What will the mechanism of giving workshop participants feedback on the results of their efforts be?
- Has workshop process been a success from NASA's standpoint?
- What should the mechanism be for reevaluating goals if they are found to be unsatisfactory (at this workshop or in the future)?
- Is there a need to define mechanisms for continuing this workshop dialogue?

Don also stated that while most participants feel that the workshops were worthwhile and successful, it is important to know if the workshop process has been a success from NASA's viewpoint. In closing, he reiterated the importance of maintaining the open dialogue among the various interest groups that were started during the workshop process.

Closing Comments

Frank stated that he was extremely pleased with this Workshop activity. He hoped that the lines of communication, which were opened in this process, would continue to remain open. He thought that now the ball had been passed to NASA to maintain this open communication. Some of the key points made at this workshop were that there needed to be more Federal interagency coordination, improved efficiencies would help achieve some near term goals, better modeling was needed and an increased emphasis on a total systems approach was necessary. Frank stated that he had enjoyed his role and that the SAIC staff had done a fine job in orchestrating these workshops. He wished all participants well in their future endeavors.

Howard Wesoky also thanked the SAIC staff and all of the workshop participants. He then shared his thoughts on where he thought the workshop process had been and what had been accomplished. He showed the workshop process schematic once more and reviewed the last workshop objectives. Howard saw the review of the roadmaps as complete for now, but that it was an ongoing process. He anticipated that NASA would move forward with their roadmaps and the technologies that were necessary as soon as possible. He saw the way forward as dealing with annual budget cycles, whether it be NASA's, Congress' or the President's, advocacy with all of the organizations NASA has become familiar with, and implementation via R&D partnerships and advice from panels. He showed the Technology Readiness Level (TRL) Chart and said that the transition between TRL 6 and 7 was sometimes not clear and that NASA needed industry's help to achieve that transfer of technology for implementation.

APPENDIX

List of Participants

First	Last Name	Company
Krish	Ahuja	Georgia Institute of Technology
Richard	Altman	Pratt & Whitney
Donald	Anderson	NASA Goddard
Richard	Antcliff	NASA Langley
Chris	Arman	City of Chicago/O'Hare Airport
Thomas	Auxier	Pratt & Whitney
Howard	Aylesworth	Aerospace Industries Association
James	Baeder	University of Maryland
David	Ballard	GRA, Inc.
Peter	Batterton	NASA Lewis
Kevin	Black	United Airlines
David	Bowles	NASA Langley
Steve	Bradford	FAA
Gerald	Brines	Allison Engine Company
Ray	Brown	Delta Airlines
Carrol	Bryant	Transportation Solutions, Inc.
Lawrence	Butler	GE Aircraft Engines
Carol	Cash	GE Aircraft Engines
Lisa	Chang	EPA
Adina	Cherry	SAIC
Kestutis	Civinskas	NASA Lewis
John-Paul	Clarke	MIT
Thomas	Connor	FAA
Vic	Corsiglia	NASA Ames
Art	Coulomb	ATA
Charles	Cowan	Cutler & Stanfield
Carolyn	Cunningham	Natural Resources Defense Council
Robert	Cuthbertson	The Boeing Company
Bill	Dalton	Allison Engine Company
Tom	Davis	NASA Ames
Ruben	DelRosario	NASA Lewis
Dallas	Denery	NASA Ames
Walt	Desrosier	GAMA
Barbara	Dillon	SAIC
Willard	Dodds	GE Aircraft Engines
John	Dodge	Allied Signal
Sam	Dollyhigh	NASA Langley
Michael	Dudley	NASA Ames
Doug	Dwoyer	NASA Langley
Dick	Dyer	CA DOT
James	Erickson	FAA
David	Fancher	GE Aircraft Engines
Tony	Fiorentino	Pratt & Whitney
Phil	Fowlie	United Airlines

Rick	Fucik	Northrop Grumman
Don	Galbraith	Galbraith Associates
Sue	Gander	Center for Clean Air Policy
Jarvis	Gantt	U. of TX-Applied Research Labs
Christine	Gerencher	Landrum & Brown
Glenn	Gilyard	NASA Dryden
Philip	Gliebe	GE Aircraft Engines
Richard	Golaszewski	GRA, Inc.
John	Goulding	BFGoodrich Aerospace
John	Graham	Los Angeles International Airport
Mark	Guynn	NASA Langley
Oren	Hadaller	The Boeing Company
Richard	Halik	Port Authority NY/NJ
William	Haller	NASA Lewis
Peter	Hart	Allison Engine Company
Thomas	Hartmann	Lockheed Martin
Tim	Haskell	Nashville International Airport
Robert	Howard	AEDC/Sverdrup
Aubre	Howell	Northrop Grumman
Dennis	Huff	NASA Lewis
Jim	Humphries	Sacramento International Airport
Tina	Hunter	FAA
Lynae	Jacobson	SEATAC Airport
Rod	Jago	SAIC
Betty Ann	Kane	National Organization to Insure Sound Environment
Rich	Kassel	National Resources Defense Council
Barry	Kiel	AFRL/PRTC
David	Koert	Wichita State U.-National Institute of Aviation Rsch
Herb	Kuntz	Lockheed Martin
Richard	Lawrence	NASA Goddard
Duc	Le	US DOE
Chi-Ming	Lee	NASA Lewis
Cindy	Lee	NASA Langley
Ellina	Levina	Center for Clean Air Policy
John	Leverton	GKN Westland
Anita	Liang	NASA Lewis
Diana	Liang	FAA
Dick	Linn	Dallas-Ft. Worth Airport
James	Littleton	FAA
Wesley	Lord	Pratt & Whitney
Stephen	Lukachko	MIT
Gary	Machles	GE Aircraft Engines
Max	Malone	United Airlines
Tom	Maloney	Dunacs/NASA Lewis
Brian	Manning	EPA
Ty	Marien	NASA Langley
Bill	Marx	FAA

Doug	Mathews	Pratt & Whitney
Peter	McCallum	NASA HQ
Ed	McQueen	FAA
Richard	Miake-Lye	Aerodyne Research Inc.
Nicholas	Miller	Harris, Miller, Miller & Hanson
John	Mitchem	AlliedSignal
Steve	Moran	White House/OSTP
Stephen	Morford	Pratt & Whitney
John	Morgenstern	Lockheed Martin
Louise	Mudd	FAA/TRW
Frank	Murray	SAIC Consultant
Kevin	Nesbitt	CALSTART
Cindy	Newberg	EPA
Richard	Niedzwiecki	NASA Lewis
Jim	Ohi	NREL
Charlie	Parente	Northrop Grumman
Bob	Pearce	NASA HQ
John	Pehrson	Camp Dresser & McKee Inc
Eugene	Peters	Landrum & Brown
Annie	Petsonk	Environmental Defense Fund
Steven	Pflaum	McDermott, Will & Emery
David	Picasso	NASA Ames
Clemans	Powell	NASA Langley
Carol	Quinn	NASA Lewis
Ron	Ray	NASA Dryden
N.N.	Reddy	Lockheed Martin
Lisa	Reuss	SAIC
Karen	Robertson	Dallas-Ft. Worth Airport
John	Rohde	NASA Lewis
Carol	Russo	NASA Lewis
Naseem	Saiyed	NASA Lewis
Dennis	Sawyer	TRW, Inc.
David	Schein	Northrop Grumman
Fredric	Schmitz	U. of Maryland
Arun	Sehra	NASA Lewis
Stephen	Seidel	White House
Paul	Senick	NASA Lewis
Ben	Sharp	Wyle Laboratories
Nancy	Shelton	FAA
Belur	Shivashankara	The Boeing Company
Rickey	Shyne	NASA Lewis
George	Siple	Camp Dresser & McKee, Inc.
Jim	Skalecky	FAA
Brian	Smith	NASA Ames
Chuck	Smith	NASA Ames
Glenn	Smith	NASA HQ
Chris	Snyder	NASA Lewis

Paul	Soderman	NASA Ames
David	Stephens	NASA Langley
Paul	Stolpman	EPA
Gary	Stowell	San Jose International Airport
Don	Sutkus	The Boeing Company
Bob	Tacina	NASA Lewis
Richard	Thompson	HMMH
Len	Tobias	NASA Ames
Mary	Vigilante	Synergy Consultants, Inc.
Ian	Waitz	MIT
Donald	Weir	Allied Signal
Gregory	Wellman	Landrum & Brown
Howard	Wesoky	NASA HQ
Chowen	Wey	NASA Lewis
Michael	White	Mitre Corporation
Tim	Wickenheiser	NASA Lewis
Bill	Willshire	NASA Langley
Keith	Wilschetz	Landrum & Brown
Ted	Woosley	Landrum & Brown
Jia	Yu	BFGoodrich Aerospace
Isam	Yunis	NASA Lewis
Rick	Zelenka	NASA Ames

List of Organizations

Company
AEDC/Sverdrup
Aerodyne Research Inc.
Aerospace Industries Association
AFRL/PRTC
Allied Signal
Allison Engine Company
ATA
The Boeing Company
BFGoodrich Aerospace
CA DOT
CALSTART
Camp Dresser & McKee Inc
Center for Clean Air Policy
City of Chicago/O'Hare Airport
Cutler & Stanfield
Dallas-Ft. Worth Airport
Delta Airlines
Environmental Defense Fund
EPA
FAA
Galbraith Associates
GAMA
GE Aircraft Engines
Georgia Institute of Technology
GKN Westland
GRA, Inc.
Harris, Miller, Miller & Hanson
Landrum & Brown
Lockheed Martin
Los Angeles International Airport
McDermott, Will & Emery
MIT
Mitre Corporation
NASA Ames
NASA Dryden
NASA Goddard
NASA HQ
NASA Langley
NASA Lewis
Nashville International Airport
National Organization to Insure Sound Environment
Natural Resources Defense Council
Northrop Grumman
NREL

Port Authority NY/NJ
Pratt & Whitney
Sacramento International Airport
SAIC
San Jose International Airport
SEATAC Airport
Synergy Consultants, Inc.
Transportation Solutions, Inc.
TRW, Inc.
University of Maryland
United Airlines
U. of TX-Applied Research Labs
US DOE
White House/OSTP
Wichita State U.-National Institute of Aviation Rsch
Wyle Laboratories