UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
OFFICE OF OCEANIC AND ATMOSPHERIC RESEARCH
1315 East-West Highway
Silver Spring, Maryland 20910

DEC 21 2001

MEMORANDUM FOR: Bruce Hicks
Director, Air Resources Laboratory

FROM: David L. Evans

SUBJECT: Summary and Action Items Resulting from the May 9-10, 2001 ARL Review

I congratulate you and your staff on the quality of the Air Resources Laboratory (ARL) review on May 9th and 10th, 2001. The review panel was deeply impressed by the quality of research being conducted by ARL, as am I. You treated my staff, other guests, and the panel members most graciously, and made the review a memorable event. I received written reviews from each of the five panelists and additional input from others who attended the review. This memorandum is to provide you with a summary of the reviewers' comments and a list of action items resulting from the review.

A detailed synthesis of the panelists' comments is attached to this memorandum. A summary of the reviewers' comments, my impressions, and suggested actions follows.

ARL Management - I would like to commend you on your effective management of ARL. The panel was highly complimentary of your management and scientific leadership. I know that the successes of the laboratory have depended heavily on your efforts.

Quality/Scope of Research - The panel found, and I concur, that the overall quality of research at ARL is very high. The reviewers noted that ARL has unique capabilities which have led to the Laboratory's being recognized as an international leader in climate monitoring and trend detection, surface radiation measurements, and atmospheric modeling. They also emphasized that ARL is a national leader in research relating to atmospheric deposition of nutrients, surface-air exchange dynamics, effects of radiation on atmospheric pollutants and climate change, dispersion dynamics, and forecasting using predictive modeling.

The panel felt that air quality monitoring and forecasting can be considered as one of the most important contributions of ARL to the government and the general public. They highlighted the fact that air quality monitoring/forecasting is one area where ARL generally has the

leading role in the U.S. and encouraged ARL's initiatives in the area of air quality forecasting. The panel recognized the necessity for the substantial infrastructure requirements for air quality forecasting to be defined, but they determined that the ARL laboratories have the interest, expertise, and collectively the necessary critical mass, to carry out this work.

Reviewers also emphasized the importance of the monitoring of climate variables and the assessment of the time series performed mainly at Silver Spring (meteorological data) and Boulder (radiation, UV, and ozone). Recent publications from these groups are at the forefront of present research. The panel described this work as a crucial NOAA effort to which ARL makes a major contribution.

Budget Constraints - The panel found that the key challenge facing the laboratory is related to base-funding levels for the scientific staff and the significant dependence of ARL on external funding. While the panel was complimentary of the quality of ARL's current research programs, many of the reviewers found that the scientific caliber and productivity of several of the Divisions are dangerously close to falling below the critical mass needed to remain effective and competitive. **In order to clarify how ARL will function within its funding constraints, the laboratory needs to develop a long-term strategic plan. Please provide me, no later than July 2002, with a comprehensive strategic plan that details ARL's scientific, partnering, funding, and staffing priorities and plans for the next five years. This plan should clearly articulate ARL's mission within NOAA and develop strategies for focusing on mission-related research, even as it accepts significant levels of funding from two external sources. Once the plan is complete, I will review it and discuss with you any issues that remain a concern.**

In addition, several of the reviewers commented on the existence of unnecessary barriers that place ARL scientists at competitive disadvantages in seeking external funding. **ARL should document examples of such barriers as they occur so that I can work with you to develop strategies to mitigate these disadvantages.**

Division Collaboration - While not ideal from an operational perspective, the panel found that the organizational structure of the six separate Divisions allows ARL to maintain strong relationships with your primary constituents. The panel also recognized that although there is a need for further collaboration among the ARL Divisions and between ARL and other NOAA entities, such collaboration can be difficult to implement. Several reviewers, however, did describe successful examples of existing collaborative activities, including: collaborations between the Surface Radiation Research Branch (SRRB) and the Atmospheric Turbulence and Diffusion Division (ATDD) in establishing climate monitoring stations that include radiation measurements; observing and modeling dry deposition to forests involving the Atmospheric Sciences Modeling Division (ASMD) and ATDD; development and deployment of fast-response airborne sensors for turbulence measurements of eddy fluxes and ocean surface

parameters from aircraft involving the Field Research Division (FRD) and ATDD; and meteorological and chemical measurements from the NOAA Twin Otter involving ARL Headquarters and ATDD.

Reviewers also suggested a variety of potential activities that would benefit from increased interactions between ARL Divisions. As an example, a very important focus of ARL is the research on the exchanges between the land surface and the atmosphere, in particular. This work has led to important knowledge about the sources of pollutants in different regions, as well as physical and chemical processes near the surface. This work involves all of the ARL locations in some way and would be one natural focus area for future development of ARL. Other examples included the modeling and measurement of wet and dry deposition, estimating the surface energy budget, and long-term trends in carbon dioxide and pollutant concentrations. Such activities should be promoted. With this in mind, I would like to remind you that the request for proposals to the Assistant Administrator Laboratory Fund encourages intra/inter laboratory coordination.

The panel also suggested mechanisms to improve inter-Divisional interactions. Among these were directing a relatively modest amount of funds to take advantage of annual meetings, workshops, or conferences with substantial ARL attendance to enhance direct interactions between relevant PIs and laboratories. In particular, setting up one meeting at the mid-point of the four-year laboratory review cycle at an existing venue with significant ARL attendance would minimize the amount of resources spent toward this objective and ensure biennial interaction.

To improve the exchange of information within ARL as well as between ARL and the other NOAA Research laboratories, the panel recommended that ARL make better use of available communications tools. I agree. **Specifically, each of the ARL Division Directors should make sure their staff have access to the NOAA Research Hot Items page. The informative monthly ARL report could also be better advertised by an email broadcast from you with a URL link when the report is published. A summary of this comprehensive report would also be valuable to ensure wider readership. Furthermore, PI research exchange programs such as released time, short-term inter-division exchanges, or cross-divisional field programs should be encouraged.**

<u>The Role of ARL within NOAA Research/NOAA</u> - The review made it clear that the relationship between ARL and NOAA Research Headquarters needs to be improved. Several of the reviewers emphasized the fact that ARL staff does not feel valued within NOAA Research. Clearly this is not a good situation and should not be ignored. **To improve this situation, ARL management needs to better provide NOAA Research Headquarters with information on the value and impact of ARL research and of the newest research opportunities. For example, ARL needs to ensure that its space within Hot Items is regularly updated. For our part, we will work to improve our understanding of this information and its communication to our constituents outside of NOAA Research.**

The panel recommended increased interaction between NOAA Research Headquarters and ARL staff to improve this situation. **The two meteorologist positions within the Office of Scientific Support have now been filled and they have been tasked with becoming intimately familiar with the weather and air quality research efforts within NOAA Research. They will be approaching ARL for program material. For its part, ARL should take advantage of these two capable analysts and ensure that they are kept current on ARL issues. I also strongly encourage you to continue to work closely with the Associate Director for Weather and Air Quality to develop and market research initiatives. In addition, because of your unique position of being collocated with NOAA Research Headquarters, I would suggest that you encourage your staff to attend the bi-weekly NOAA Research full staff meetings.**

Finally, to help address concerns expressed by ARL about the amount of overhead charged by NOAA Research Headquarters, I will ask you to comment on the plans for the NOAA Research Headquarters review. These plans will be made available for comment at the January 2002 Senior Research Council (SRC) meeting. I also recommend that you participate in the discussion of the review results at the SRC meeting following the review.

Small Aircraft - Several of the reviewers found that the small aircraft used by ARL's Field Research Division (FRD) offers a complementary capability to NOAA's large research aircraft. A major hurdle, however, to its continued operation are the concerns of NOAA's Office of Marine and Aviation Operations (OMAO) as to the safety of the ARL LongEZ (N3R). **ARL needs to continue to work with NOAA Research Headquarters and OMAO to demonstrate the safe use of this small aircraft. Please submit a detailed plan by February 28, 2002, describing how FRD will certify the safety of its small aircraft operations.**

In conclusion, I again express my appreciation for organizing and managing an excellent review. If you have any questions about this memorandum, my recommendations, or any other ARL/NOAA Research Headquarters issues, Stephanie Harrington is your laboratory liaison, and she will be glad to help you. She can be reached at (301) 713-2465 ext. 160, fax (301) 713-0158 or e-mail stephanie.harrington@noaa.gov. As discussed above, I would ask that you distribute this report as well as any follow up materials throughout ARL to further aid communication between ARL and NOAA Research.

Attachment

SYNTHESIS
ARL REVIEW PANEL COMMENTS

The following is a synthetic report created by combining the written comments made by six reviewers at the Air Resources Laboratory (ARL) review, held on May 9-10, 2001. Under the terms of the Federal Advisory Committee Act (FACA), the panelists provided individual written reports to NOAA's Office of Oceanic and Atmospheric Research (OAR) Assistant Administrator. Their separate reports were combined and edited (solely to reduce duplication and repetition) to produce this synthesis which as accurately as possible reflects their opinions. Nothing was added to or removed from this report by the editor. Numbers in parentheses following specific comments indicate the number of panelists who made similar remarks.

NOTE: Several of the reviewers noted that they did not feel qualified to pass judgment on all of ARL's efforts, since many of the efforts are outside their area of expertise. Their preferences/foci were mostly because of personal research interests and understanding, not because of any perceived deficiencies on the part of the other Divisions/areas of research.

SYNTHESIS

Collectively, the Divisions of ARL provide a complementary research capability that covers the ARL Strategic Plan, which in overview: "...conducts research on processes that relate to air quality and climate, concentrating on the transport, dispersion, transformation, and removal of trace gases and aerosols, their climatic influences, and exchange between the atmosphere and biological and non-biological surfaces." Each of the Divisions fills a somewhat different niche in this rather general overview, and each has a somewhat different mix of activities to carry out the particular Divisions' objectives, and the objectives of the different government agencies for which they provide support. Overall, the ARL research program is impressive--especially in view of the difficulties the Divisions face due to limited funds, geographic separation, and divided allegiances.

The Review

This review is based on the review meeting, and on reading material provided before, during and after that meeting.

The format of the meeting was well-suited for a two-day Laboratory review, although the panel was presented with a wealth of information at a very fast pace with little time for contemplation. (2) The review was very well organized, both scientifically and logistically. Small touches, such as having powerpoint presentations loaded onto the same computer, made the review run very smoothly.

Overview talks by management and leading scientists gave the panel a clear view of the scope of ARL. Especially enlightening and interesting were the presentations by Tilden Meyers (ATDD) on land surface processes and water and carbon flux budgets, Jerry Crescenti (FRD) on air-sea

interaction research, and Robin Dennis (ASMD) on coastal wet and dry deposition of nitrates and ammonia.(1) A set of excellent posters filled in details of the science projects. Much thought had clearly been given to all of the posters and presentations. They were well-prepared, stimulating, informative and of high quality.(2) The discussions with members of the laboratories were substantial, highly informative and revealing, providing a sound understanding of the mission, objectives and research thrusts of each laboratory. Bruce Hicks and the Division heads should be commended for their cooperation, willingness to answer questions and provide additional materials and well-organized presentations.

The ARL review materials provided before the Research Triangle Park meeting were a concise, useful summary of the Laboratory which included the organizational structure and strategic plan of ARL, the organization of the meeting, and abstracts of the scientific presentations. The CD containing the presentations and poster papers was also very useful in recalling details of the presentations.(2)

The PIs did comment that they perceived no changes in ARL resulting from the previous review. This somewhat deflating (to the reviewers) comment is understandable since a couple of the main recommendations have to do with closer interactions among the laboratories and higher funding levels--easy conclusions to reach but nearly impossible to implement.

Recommendations

In future reviews there should be more self-assessment. It is valuable for the unit(s) to take their own stock of where they are today, relative to where they were X years ago and where they want to be Y years from now. This should include reflection on what previous reviews identified as issues – and what steps have been taken to address them.

Future panel reviews should be sequentially carried out at the various ARL Divisions, and the panel report (and the NOAA and ARL) responses should be distributed to all ARL personnel and to each panel member.

ARL Management

The current management of ARL is effective. Bruce Hicks devotes much effort to maintaining the viability of ARL. This is a large personal effort, which is both rare in an individual and yet essential for the ability of such a laboratory to function. Much of the effort involves decisions about the fair and reasonable distribution of insufficient funding and the petitioning for maintenance of the budget. The success of the laboratory depends heavily on this effort. He also appears to devote much effort to being involved with the science going on in ARL and has a very realistic view of the research being performed and where it should be going. By all indications Bruce has done an excellent job in shaping a more cohesive ARL.

The individual laboratories have their own strengths and challenges, and the management of these distinct and geographically dispersed units is a difficult task. Each branch director clearly has their own style; each of them commands the respect of their staff.

The PIs had mostly good things to say about the management structure within ARL, and generally felt that their superiors within ARL were good managers and were coping as best they could in difficult circumstances. There was, however, a general feeling amongst the staff that the branch chiefs are too busy to become fully involved in the research issues in the branches. The amount of hands-on science performed by each of the six directors varies greatly: from almost none to a heavy involvement. This seems to depend on both the size of the division and the problems associated with maintaining funding. (Other issues might also play a role.)

Recommendations
One caveat to the above is that the Atmospheric Sciences Modeling Division needs a permanent director.

Budget/Staff Constraints
The key challenge facing the laboratory is related to the budget. The primary issue appears to be base-funding levels for the scientific staff. The ARL Divisions seem to be operating in the model of today's State run universities, i.e., they are "NOAA-assisted" entities, with NOAA base funding accounting for much less than 50% (~25-30%) of the units operating costs.(3) About the same amount is obtained from DOE and more from EPA.

Such external funding is potentially unstable in the medium to long term. This mode of operation has many ramifications, including the demand it places on the staff and directors to work outside of NOAA to secure funds.(2) The constant need to procure this funding and to provide documentation of results to external supporters means that some scientists are publishing rather less in the peer-reviewed literature than would otherwise be possible. Since publication in international journals is a measure of success, this is a situation that could potentially damage the career paths of the scientists.

In addition, projects funded in this way tend to have shorter completion cycles, with more accountability/deliverables, and often with a tension or mismatch between job performance metrics (e.g., how to assign credit for securing a project to pay your salary vs. the paper that did not get written because of the proposals written; how to weight credit between non-NOAA and NOAA funded activities, and how outside funding biases research directions, etc.).

Individual and collective scientific research in ARL do excel in spite of a potentially severe lack of base funding and an apparent strain on manpower. Federal manpower in almost all of the branches, however, is decreasing in the long term. Some lab components (the Boulder and Oak Ridge laboratories specifically), despite their high degrees of innovativeness, scientific caliber and productivity, are teetering dangerously close to falling below the critical mass needed to remain effective and competitive.(3) Without additional recruitment some aspects of the research performed are possibly threatened. Further erosion of investigator and support positions at ARL Divisions should not be allowed.(2)

These aspects of ARL manpower and funding are the primary concern for both the PIs as well as the Division directors and lead to a lack of morale amongst the staff, which again may impede

their productivity. ARL staff, in particular the younger scientists and technical staff, feel a great deal of uncertainty and stress, the pull of too many small projects as they attempt to stay funded, and concern that the situation is not going to improve.(2) Some of the younger scientists are concerned about whether they will have jobs in one year, even if they are working productively.

Finally, there is a bimodal distribution of employees' ages, with one peak approaching retirement age. As a result, there will be many retirements within a few years, and likely few replacements since the outlook for hiring replacements in the foreseeable future is bleak. This will mean loss of expertise and leadership within the Laboratory, and is an area that should be addressed.

Recommendations

The strategy that ARL appears to be following regarding the budget is: (1) follow the funding models currently in place within the Lab with an important non-NOAA element; (2) work within NOAA to increase the core funding base; and (3) look towards new initiatives to provide significant new resources. This overall strategy seems reasonable, but the impression is that OAR has not sent a clear signal regarding whether it supports ARL's pursuit of strategy #1. This decision has many implications, but a clear position needs to be taken. If the current model is endorsed, then there need to be some guidelines developed that set some checks and balances and that remove unnecessary barriers that place ARL scientists at competitive disadvantages in seeking external funding.(2) If the model is not endorsed, then the choices are to find a way within NOAA to increase base-funding ***or*** to undertake a significant refocusing of ARL to realign activities within NOAA funding levels.

Given that it is unlikely the funding base will improve dramatically in the near future, more of a focus on the core areas of research could improve conditions at ARL. These include air quality modeling, a growing capability in air quality forecasting, air-surface interactions, and climate. More recent work on the atmospheric deposition of nutrients in coastal watersheds and estuaries should also be emphasized. If the base funding level can be brought up even to 40% or so, it should be focused on these areas. 50% would be even better. A renewed commitment to core areas, modest increases in funding, and communication of this commitment to the PIs will help to improve morale, keep talented people from leaving, and maintain the high quality of work at ARL.

In addition, some of the external overhead generated by ARL should be given back to ARL headquarters, and then some of it should be returned to the local divisions at which it was generated. This mechanism was recently put into place at many universities, and the money must be used to generate future research grants.

Finally, associations with academic institutions have been exploited to some extent and, with careful planning, could provide a stable environment for future growth.

Division Diversity/Collaboration

The different branches of ARL focus on different aspects of the NOAA mission within the general themes of air quality and modeling, atmospheric effects on coastal areas, and climate.

ARL is also spread across six locations, all or most of which have which have a history that is longer than that of NOAA itself. This is reflected in the specific missions of several of the Divisions, which provide focused meteorological and atmospheric chemistry support for other federal agencies. While not ideal from an operational viewpoint, the continued existence and separation of the six divisions allows each of them to maintain a relationship with their most important clients. It also allows each division to build relationships with diverse local institutions. Such relationships should be encouraged, if ARL as a whole is to prosper.

This long history of providing support for other government agencies and the geographical dispersion has led to an unusual organization where each of the Divisions serve different "masters" and are dependent on other government agencies for the bulk of their support. Of necessity, this leads to divided loyalties.(2) It is a formidable challenge to bring these individual Divisions, which historically have had little to do with each other, together into some sort of unified structure and encourage cooperative projects among them. Bruce Hicks has tried hard to do this, and has succeeded to a surprising extent.

Equally important is that the Divisions need to be receptive to collaborative activities; and they do show they have a genuine desire to interact and collaborate. There are very positive exchanges between (for instance) data collection, data analysis, and modeling efforts among the different branches. The way that this is done is to focus on the common aspects of the research and support activities, and incorporate them into an overall organizational structure of ARL. The ARL Strategic Plan spells this out, and provides the foundation for an overall coherent structure.

One way to ensure interdivisional collaboration is to make sure that it is in the best interests of the Divisions to do so. The panel saw evidence of how this works in ARL during the review. Some examples are: collaborations between the Surface Radiation Research Branch (SRRB) and the Atmospheric Turbulence and Diffusion Division (ATDD) in establishing climate monitoring stations that include radiation measurements; observing and modeling dry deposition to forests involving the Atmospheric Sciences Modeling Division (ASMD) and ATDD; development and deployment of fast-response airborne sensors for turbulence measurements of eddy fluxes and ocean surface parameters from aircraft involving the Field Research Division (FRD) and ATDD; and meteorological and chemical measurements from the NOAA Twin Otter involving ARL Headquarters and ATDD. There are many more such activities that could also be cited, but still more collaboration would be beneficial to ARL, since there does seem to be good complementarity across the ARL Divisions. (Understandably this is not easy as even interactions between floors in the same building are sometimes disappointingly minimal.)

As an example, a very important focus of ARL is the research on the exchanges between the land surface and the atmosphere over the continental USA, for which a variety of observational techniques and models have been developed; this work has led to important knowledge about the sources of pollutants in different regions, as well as physical and chemical processes near the surface. This work involves all of the ARL locations in some way and would be one natural focus area for future development of ARL. Since this work is unique to ARL, it could be developed further as a flagship NOAA effort to provide analyses and forecasts of air quality. ARL is clearly leading the scientific field in this area.

The presentation by Hicks also brought out areas of research that fit into a unified scientific plan across ARL. He emphasized that it is important to couple research and monitoring activities, but that there is pressure within NOAA to separate these activities. Within the scientific areas of ARL, such as modeling and measurement of wet and dry deposition, estimating the surface energy budget, and long-term trends in carbon dioxide and pollutant concentrations, it is important to keep these activities closely linked.

Related to this is collaboration with other NOAA Laboratories. Some of the younger PIs feel that they are in competition with other NOAA Labs because both are scrambling for the same research and salary funds. The system should allow scientists from the different ARL Divisions to work together, write proposals together, and combine the strengths of the different ARL Divisions (or different NOAA Laboratories) to make a stronger whole out of the smaller parts.

There are activities in ARL that are also carried out by other NOAA Laboratories which could profit by closer ties to ARL. Examples are surface-based eddy flux measurements of energy, momentum and carbon dioxide that are carried out by both ATDD and the Climate Monitoring and Diagnostics Laboratory, and trace gas measurements in the planetary boundary layer (PBL) carried out by the Aeronomy Laboratory that could benefit by incorporating flux measurement capabilities of ATDD and perhaps modeling efforts by ASMD. It would be of mutual benefit to both ARL and these other Laboratories if there were more interactions among them.

Recommendations

The panel recognized that there are ways to foster further collaboration among the Divisions, but that there are problems implementing them. Such things as more interdivisional meetings, exchange visits, and interdivisional seminars have been suggested before, but of course they exact a toll in both money and time--both of which are in short supply. In order to foster communication, it had also been recommended that ARL have yearly meetings for all six Divisions to get together. This was not adopted due to lack of funding.

Overhead funds should be used by ARL management as seed money to facilitate production of major joint-division proposals. A relatively modest amount of funding could be directed to annual meetings, workshops and conferences (perhaps timed with professional meetings) to enhance direct interactions between relevant PIs and laboratories. Furthermore, PI research exchange programs such as released time (as done at Universities) and short-term (months) interdivision researcher exchanges, should be encouraged in order to facilitate direct interactions among individuals having specific expertise and approaches to multi-disciplinary, multi-media problem solving.(2) In addition, in this day of electronic communication, cross-laboratory websites can be easily established to provide vehicles for informational exchange and synthesis. Such websites are already in existence among universities and between university and state/federal laboratories. (Some of this was recommended by the last panel, but without the above suggested funding mechanism.)

As well as providing the review panel with an overview of the science performed in all branches, the opportunity for members of the six Divisions to get together was clearly a highlight of the review. Similar interactions between the branches should be arranged whenever possible. A

review of this type seems to occur every 4 years. If, in addition, there was a Laboratory-wide internal review with presentations every 4 years as well, but offset from the external review by 2 years, then at least there would be one general meeting every 2 years, but at only a quarter of the cost of having one every year.

A better system to produce and distribute quarterly and annual activity reports for each of the divisions should be developed. An annual report, suggested by the last review panel, has been implemented on the ARL web page. Beyond that, the Division directors should make sure their staff know about the monthly reports that come out from each lab; everyone can at least read the table of contents. Perhaps there could be quarterly or yearly summaries as well (as long as the writing of reports does not add significantly to the present workload - best if they can be taken nearly intact from monthly or other reports).

Greater collaboration with university, non-profit as well as private research-based institutions is also encouraged. This can in part be accomplished by providing more student fellowships, post-doctoral positions and exchange programs for staff among various ARL divisions.

The Role of ARL within OAR/NOAA

In general, NOAA and ARL need to break down barriers, both between ARL divisions, as discussed above, and between ARL and upper levels of NOAA management and other NOAA Laboratories. It is not clear that NOAA's administrator or OAR is as aware of what ARL does (or its low dollar cost to NOAA) as they should be.

The relationship between ARL and OAR was mentioned several times during the review. The general impression conveyed by ARL staff is that OAR is not supportive of ARL. This impression seems to be driven in large part by budget pressures, but it goes beyond that - with an impression that ARL is not valued within OAR.(2) Clearly this is not a good situation and should not be ignored.

One of the more revealing sessions of the review was the frank discussion the Review Panel held with the Laboratory PIs. Many of the points that they made were not unique nor surprising. They feel that they are carrying out NOAA's mission in their role as providing services to other government agencies, but are not receiving as much recognition from NOAA as their accomplishments merit. One commented that NOAA generally seems more interested in the ocean than in the atmosphere.

Recommendations

ARL management needs to better provide OAR with information on the value of ARL research and of the newest research opportunities. OAR then needs to better present this information to NOAA management, so that it will have more clout with the American people, Congress, and other U.S. environmental agencies. NOAA and ARL will thus be in a position to obtain larger shares of available environmental research resources. Congress needs to be reminded that NOAA mission includes air quality research, while the EPA mission is air quality regulation.

This is admittedly a period of funding cuts rather than increases, which leads to stretched resources in all government agencies. Even if NOAA is unable to offer more stable and higher funding to ARL in terms of additional positions, it should strive to improve the morale of the work force in as many ways as possible, recognizing ARL's contributions to NOAA's mission.

Sending clear signals about funding strategies, increased attention to this perception by Bruce Hicks and the director of OAR, more involvement of ARL within NOAA strategic planning, and increased interaction between OAR and ARL staff could improve this relationship.

Quality/Scope of Research

ARL scientists show a deep understanding of their work, of its limitations (such as the continual need to refine models), and of its importance to several national requirements. The overall quality of research and other work at ARL is generally very high.(3) From top to bottom they are doing high-quality work, and are to be commended for their efforts. No other laboratory or agency has the skills to carry out ARL's mission.(2)

There was much evidence of good solid work aligned with the scientific and technical goals of ARL. The research themes identified by ARL are carefully chosen, and reflect the strengths of the individual components and the available opportunities. It is clear that ARL activities also strongly support the identified NOAA strategic themes.

All of the important on-going activities cannot be listed, but some of this work is of international leading quality while other components are leading national efforts. Components of the research can be regarded as leading the present international efforts include: the climate monitoring and trend detection, the maintenance and analysis of the surface radiation measurement network (including the UV), and many aspects of the atmospheric modeling.

Particular national efforts for which NOAA bears responsibility, and where ARL possesses unique capabilities, included the following: 1) atmospheric deposition of nutrients (in particular nitrogen) and other anthropogenic pollutants (metals, organic compounds) to sensitive terrestrial and aquatic environments, especially estuarine and coastal waters, 2) air-surface exchange dynamics; specifically the roles they play in mediating deposition or air pollutants, 3) The essential and integrative roles UV and other forms of radiation play in mediating emission, deposition and utilization of atmospheric pollutants, and their relationships to changes in climate, 4) multi-media emission, dispersion and deposition dynamics as they pertain to airshed-/watershed interactions, formulating and managing allowable nutrient and other pollutant inputs to sensitive waters (i.e., TMDLs), and 5) forecasting using predictive modeling (including the READY activities and website). In addition, the small aircraft observations are quite unique and provide valuable information to the community. The combination of these observations with process modeling studies is an asset to ARL and growth in these areas should be encouraged.

The multi-disciplinary, multi-media approaches being utilized by all laboratories is particularly impressive and there are many opportunities for complementation (in relevant fields) that avail themselves within and among the laboratories. It is obvious that the "glue" needed to create and

maintain complementation is modeling. Fortunately, ARL is blessed with highly relevant and expert modeling capabilities throughout the laboratories (with essential critical masses at Research Triangle Park (RTP), Silver Spring and Oak Ridge.

Air Quality

In terms of the importance of ARL's mission, air quality monitoring and forecasting can be considered as one of the most important contributions to the government and the general public. Air quality monitoring/forecasting is the area where ARL generally has the leading role in the U.S., and this should be maintained and strengthened.(3) ARL has identified some exciting new initiatives related to air quality forecasting and multi-media modeling. These are important new initiatives, which build upon existing strengths, and address important National needs.

The forecasting of air quality (both its physical and chemical components) is a priority in many nations with the meteorological agencies often playing the lead role. The WMO GAW Urban Research Meteorology and Environment (GURME) project was developed in response to the requests of the National Meteorological and Hydrological Services (NMHSs) and builds upon the recognition that NMHSs have an important role to play in the study and management of urban environments because they collect information and have capabilities that are essential to the forecasting of air pollution and the evaluation of the effects of different emission control strategies.

While the NMHSs will extend their role in various directions in the future, they will remain centered on the traditional activities related to meteorological monitoring, forecasting, and modeling (both meteorological and chemical) and their respective application to air quality problems. This direction should be supported and the forecasting of air quality is best done within the operational context of weather forecasting, since the meteorological conditions control the transport of pollutants. The document prepared by ARL, "*Predicting Air Quality*," makes a powerful case for this activity and the role of ARL. In addition to those activities outlined in *Predicting Air Quality*, there are other aspects of air quality forecasting that need to be addressed and fit within the ARL/NOAA mandate.

Multi-media

There is a growing awareness of the relationship between the atmosphere, biosphere, and oceans. This coupling of different earth systems is recognized at ARL, and work is beginning on these "multimedia" problems. (The coupling of measurements with models and theory continues to be necessary, of course.) The strengths and benefits of the multi-media, multi-disciplinary approach for integrating atmospheric research in terrestrial and aquatic (including, freshwater, estuarine and coastal) problem solving (from water quality/fisheries habitat and resource and climate change perspectives) were apparent among the PIs' presentations.

Climate

Another area of great importance is the monitoring of climate variables and the assessment of the time series. This work is performed mainly at Silver Spring (meteorological data) and Boulder (radiation, UV, and ozone). Recent publications from these groups are at the forefront of present research. This is a central NOAA effort to which ARL makes a major contribution. (Note that

despite the careful and influential work of the climate group at ARL on water vapor and other issues, there is far more to climate than can be carried out by any one laboratory. But ARL can and does make important contributions to climate research in a few select areas.)

Development of inputs to (and evaluations of) interannual and seasonal climate models, which are also moving towards models that link the ocean, atmosphere, and biosphere. ARL also has expertise in the development of a number of parameterization modules for such models, e.g., solar radiation, surface energy processes over plant covered surfaces, and radiative effects of aerosols. In addition, ARL is the leader in the analysis of the global rawinsonde database.

Future Directions
ARL-based modeling, transcending local and regional scales, has identified particularly significant research areas requiring further field and laboratory work. These include; 1) Air-surface exchange, UV and other forms of radiation, field emission and deposition measurements and verifications, biogeochemical and ecological responses (including risk assessments) to a variety of atmospheric depositional events (on episodic and chronic scales) and amounts of nutrient and pollutant inputs impacting productive and nutrient cycling characteristics of terrestrial, lacustrine, estuarine and coastal ecosystems.

Nationally, there are unprecedented changes in land use and resultant anthropogenic emissions taking place. The implications of these changes for air and water quality, and their potential roles in climate change (e.g., greenhouse gas emissions) are of vital importance to our coastal resources and of central relevance to NOAA's overall mission. One example provided was the proliferation of livestock operations in the US Midwest and mid-Atlantic states. The rapid growth of hog and poultry operations in coastal airsheds (e.g., Chesapeake Bay, Pamlico Sound) has, in some locations, led to at least a doubling of ammonium deposition in N-sensitive watersheds and coastal waters (presentations by Robin Dennis and Alice Gilliland). The implications of this atmospherically-mediated form of coastal eutrophication are manifold from water quality, fisheries habitat and resource perspectives. This issue further illustrates the importance of incorporating atmospheric emission and depositional dynamics in the context of multimedia (air-land-water) considerations of environmental "drivers" of coastal change. It is clear that the PIs working on these issues at Silver Spring, RTP and Oak Ridge are on the forefront of addressing this issue in an essential multi-media, multi-disciplinary manner.

There are additional informational needs requiring collaborative multidisciplinary efforts among the ARL divisions. One example is timely and appropriate measurements of air-sea interactions as they pertain to emission and deposition dynamics in coastal waters. Another is the development of a network of UV irradiance/reflectance measurements in estuaries and coastal ecosystems undergoing a environmental and ecological changes. Relevant ecosystems include: 1) estuaries, embayments and sounds in the Northeast (Narragansett Bay, Gulf of Maine, Long Island Sound), 2) the nutrient-sensitive mid-Atlantic estuaries and adjacent coastal waters (Chesapeake, Pamlico Sound, Southeast Atlantic Bight), 3) Florida Bay, 4) the bays and estuaries of the Gulf of Mexico, including the Mississippi River plume in the Gulf, 5) West Coast estuaries and bays requiring even rudimentary knowledge of interacting effects and ecological impacts of atmospheric, land-base inputs and irradiance. In this regard, the Idaho and Boulder

divisions have both the technologies and expertise to provide relevant measurements and model verifications. Closer collaborative efforts between these divisions and the RTP/Silver Spring and ORL should be encouraged to address these important multi- and cross-disciplinary issues.

Recommendations

NOAA should do all it can to enhance programmatic strength in ARL. This should include, developing and enhancing research strengths in crossdisciplinary aspects of the key areas listed above, providing critically-important new positions in research areas linking atmospheric emission and deposition dynamics to ecosystem responses, including water quality, habitat and resource, as well as climatically-induced changes. Specific recommendations include:

Air Quality

An extremely important component of ARL is the collaboration between the various groups; there are very positive exchanges between (for instance) data collection, data analysis, and modeling efforts among the different branches. A very important focus of ARL is the research on the exchanges between the land surface and the atmosphere over the continental USA, for which a variety of observational techniques and models have been developed. This work has led to important knowledge about the sources of pollutants in different regions, as well as physical and chemical processes near the surface. This work involves all of the ARL locations in some way and would be one natural focus area for future development of ARL. Since this work is unique to ARL, it could be developed further as a flagship NOAA effort to provide analyses and forecasts of air quality.

The operational forecasting of air quality is a big undertaking and requires a long-term commitment. The infrastructure requirements to support air quality forecasting need to be defined. For example, What differences are there in the meteorological infrastructure needs (models, measurements, etc.) for air quality vs. weather prediction? What data assimilation tools are needed to support air pollution forecasting? The answers to these questions require a focused research effort. The ARL laboratories have the interest, expertise, and collectively the necessary critical mass, to carry out this research. For example it can pull together the modeling strengths at RTP and Silver Spring, the field testing in the East and monitoring activities associated with Oak Ridge and Boulder, the urban and real time response components at Las Vegas, and the aircraft campaign craft element contributed by Idaho Falls.

Specific areas in air quality meteorology that should be augmented (increased funds and staff) in the future are those that will be of increasing importance to the nation and those in which ARL already has significant expertise. These include:

- The making of air quality forecasts (meteorological and concentration) for short-term (minutes to hours) emergency responses (accidental and terrorist) on the urban canyon scale and for 24-48 hours on the urban/regional scale. Such forecasts need be made with improved versions of meteorological (e.g., RAMS, MM5, and WRF) and air quality models (e.g., UAM-V, CAMX, MODELS3) currently run at ARL. Increased funding for the development of these models was recommended in the previous review, and that such a forecasting capability should exist within NOAA was recommended by the NRC and USWRP. Such activities certainly fall within NOAA's mission to protect the nation's lives

and property.

- With respect to emergency response forecasting, ARL management needs to resolve the disagreement with LLNL/ARAC on how to divide the effort between the two of them. LLNL should continue to focus on DOE/DOD sites without local ARL measurement facilities, and ARL should continue to focus on DOE sites where it has local measurement facilities. In addition, in terms of general urban emergency releases, LLNL should take the lead in those involving radioactive or biological releases, while ARL should take the lead in those involving chemical releases. Both should share information and techniques, to strengthen both national capabilities.

Finally, at the bottom of p. 4 of the ARL Management Overview, it is written that "ARL will concentrate on pollutants of the future," with examples of nitrogen compounds in coastal areas, and atmospheric mercury. These are actually pollutants of the present (along with ozone and airborne particles); ARL and others need to be thinking of present and new chemical or industrial processes that will in fact produce the pollutants of the future.

Multi-media efforts

Development of multi-media modeling (e.g., with MIMS) of the environmental impacts of human activities, including wet and dry deposition mechanisms, should be also be augmented.(2) Environmental impact modeling is moving towards models that link the ocean, atmosphere, and biosphere, and ARL has expertise in at least two of these. This is an area of national and international research, informational and management need. The formulation of total mean daily loads (TMDL) of nutrients, a nationwide undertaking in 200+ watersheds (mandated under EPA), will rely on multi-media efforts at delineating land-based from atmospheric inputs of nutrients and other pollutants. The multi-media modeling and assessments efforts underway in ARL divisions are a critical component of the TMDL process.

While Bruce Hicks did seem to strongly support the multi-media approach, only limited enthusiasm for this exciting and compelling aspect of ARL's mission among laboratory directors was apparent. This tremendous strength (among laboratory PIs) should be appreciated at the NOAA directorate level as well, for it represents a key course for the future, both from programmatic and funding priority perspectives.

Small Aircraft

The future of small aircraft at NOAA seems to be an issue. NOAA clearly should maintain and use appropriate aircraft for the science and monitoring missions in which it is engaged. These will not always be large (or small) aircraft. A flexible, capable, and cost-effective aircraft program should be the goal. (Note that ARL has a [unique?] capability in this regard, as the director of the Idaho Falls division owns and flies his own plane in support of NOAA missions at very low cost. This cannot be taken for granted in the long term, however.)

Future Directions

Overall, the mission of the ARL program as well as NOAA's overall mission could be significantly strengthened if other branches of NOAA's research arm could be encouraged to join ARL (with appropriate support) in addressing local, regional and global issues pertaining to man-

induced as well as natural change in the coastal zone. Branches that come to mind include; 1) NOS and its coastal research labs, 2) the Coastal Ocean Program, 3) the National Marine Fisheries Service, 4) National Weather Service, and 4) the constituent programs under the Oceanic and Atmospheric Research Program.

All the above NOAA Programs have a clear stake in coastal water quality, habitat and climatic change issues facing the nation and globe. A closer union of these branches of NOAA culminating in a clearly-articulated document that outlines how NOAA is using its research prowess and collaborative capabilities to address these issues will undoubtedly help identify NOAA's and ARL's roles more clearly to the Department of Commerce, the public, and ultimately the legislative and executive branches mandated to address and support coastal issues deemed high priority to nation. There should be little doubt that issues pertaining to man's ever-present encroachment on coastal water quality, fisheries and recreational resources are near the top of the list.

Individual division comments

In terms of the individual divisions, each has different strengths and different problems.

Headquarters

In Silver Spring, a key issue is maintaining critical mass. The number of personnel has dropped.

Recommendations

A few new hires should be made to keep this a viable operation for more than just administration and a few groups working on climate and the READY model.

Atmospheric Sciences Modeling Division (ASMD)

At ASMD, the key issue is the relationship between NOAA/ARL and the EPA. While a good relationship exists with Gary Foley at EPA, this may be sensitive to personnel changes in the future. Presently, PIs at the Division feel under pressure to work for rather than with EPA, and ignore the rest of NOAA's mission.

Recommendations

A permanent director is needed at ASMD who will effectively advance the relationship between ARL and EPA. While EPA (and the general public) benefit from the relationship at present and should continue to benefit, it could be put on a more even footing.

Atmospheric Turbulence and Diffusion Division (ATDD)

ATDD has a long history of quality research on diffusion and dispersion, dating back to Frank Gifford's pioneering research, as well as on air-surface exchanges of energy, momentum, and trace gas species, especially over vegetated canopies and complex terrain. ATDD is the premier government laboratory in the area of air-surface exchanges and they cover the spectrum of developing instrumentation for surface layer measurements, carrying out field studies of air-surface exchange over different types of vegetated surfaces, over complex terrain, and throughout the diurnal cycle. They have made special efforts to study the nocturnal PBL,

including wave-turbulence interactions and pressure perturbations. This has recently been receiving increasing emphasis because it is relatively less well understood compared to the daytime PBL. They also seem to be doing a reasonable (or better) job with their modeling work on dispersion and air pollution. ATDD has also forged many collaborative links with other ARL Divisions, as well as other government agencies and universities.

Overall, research in the areas of dispersion, air-surface exchange, and climatological observations is expected to continue to be important in the coming years, as issues of importance to society continue to materialize in these areas. Increasing urbanization and power consumption, and changes in agricultural and forestry practices will continue to generate problems that will need to be addressed by research of the type carried out by ATDD. They can provide the parameterizations and data verification needed by the models developed by e.g. ASMD, ARL Headquarters, as well as other research institutions.

Recommendations
ATDD would benefit most from better communication with ASMD and Silver Spring.

Field Research Division (FRD)
Compared to the other Divisions who have more-or-less mostly evolved with the times, this Division has undergone a metamorphosis under Tim Crawford. From its previous focus on providing meteorological support to the DOE Idaho National Engineering and Environmental Laboratory (INEEL) and capabilities to carry out diffusion studies using tracers, and deploying tetroons and "smart" balloons, it has now expanded into the area of instrumenting and deploying small environmental research aircraft for a variety of studies mostly related to air-surface exchange and ocean wave effects on the atmosphere.

FRD has developed many of the airborne instruments needed for this research inhouse because their small payload limitations require instruments that are often smaller than what is available commercially. The smaller aircraft offer a significant advantage in deployment cost and minimum flight altitudes, but at the price of limited range and payload, and single pilot operation. Therefore, this capability is complementary to large research aircraft. There is a definite role for these aircraft, for example, in air-surface exchange studies, especially studying variations in fluxes over heterogeneous surfaces or over coastal areas where repeated low-level flights over the same track are required. The operating cost of an aircraft such as the LongEZ is a small fraction of a large research aircraft, and therefore it can be a very cost-effective research platform.

However, because they have had to "sell" this capability to users who were unfamiliar with what could be done, they have had to devote considerable time and effort trying to convince program managers to use their facility and have been forced to operate on a shoestring. It is not easy nor cheap to develop very small instruments for many of the required measurements, and they are really strained to be able to provide the capabilities that are needed and that they want to provide for this type of research aircraft. This is understandable, since the cards are stacked against them to some extent by advocates of large aircraft. At the same time, this is a unique capability with a very definite and unique role to play in atmospheric research.

Crawford's group is enthusiastic, easy to work with, and interested in doing good science with small aircraft.(2) Currently, however, FRD seems a bit short of inhouse scientific expertise to take advantage of these capabilities. They have done a good job of circumventing this problem by collaborations with outside scientists with excellent expertise in the area of aircraft data analysis and interpretation.

FRD has taken the initiative by actively seeking out other funding sources. They have been reasonably successful in this effort, which can be traced to the director and some of the other scientists there. There should be no illusions about the ease of this pathway, however. Many proposals were written and submitted in order to obtain adequate funding to keep the lab running. This is time that could be spent doing work for NOAA if the level of base funding were higher.

Recommendations
It would be very desirable to "institutionalize" the small research aircraft capability to the extent that some sort of base funding could be secured to provide some of the basic costs of keeping aircraft like the LongEZ available for research, documenting the performance of the research instrumentation, and carrying out more detailed analysis and interpretation of the data.

The use of "smart balloon" technology developed by FRD should be supported. They can play a crucial role in Lagrangian experiments such as the Aerosol Characterization Experiments (ACE-1 and 2) as tracers of air parcels as they are advected downwind, and provide in situ measurements of thermodynamic variables along their trajectory. The balloons can follow an airmass which can be periodically sampled by intensive aircraft measurements to evaluate budgets of trace atmospheric constituents over a period of several days. There will be more of this type of experiment in the future, especially in the marine PBL.

Special Operations and Research Division (SORD)
The Las Vegas Division is another example of one unit of ARL working very successfully more or less for another agency (in this case DOE).

Recommendations
Turf battles (such as with the National Weather Service concerning meteorological support) should be avoided, and this mission should continue.

Surface Radiation Research Branch (SRRB)
The Boulder Division provides valuable services to other NOAA, government, and external labs and seems to be doing a fine job.

Concluding Remarks
Overall, few weaknesses and numerous strengths in ARL's research program were noted. Both can be addressed and enhanced given appropriate representation and integration of ARL's activities within the larger framework of NOAA's mission. This calls for creative and convincing packaging of the essential multi-media, crossdisciplinary approaches that will be needed to address overlapping issues of air- and water quality that impact our coastal environments. NOAA must take the lead in addressing these issues and it has the research arsenal (ARL and

complementary coastal laboratories as well as climatological programs) to do so. At the ARL PI level, and in Dr. Hicks' office, the knowledge base, creativity and desire needed to accomplish this lofty goal are in place. One of the key challenges facing ARL and your office is whether this enthusiasm and talent can be more effectively supported at the agency level.

In summary, ARL should be given high marks for relevancy, research excellence and productivity under the continuing leadership of Dr. Hicks. However, closer collaboration and expansion along the lines of multi-media, interdisciplinary research is needed to address the complex array of air-water-land interactions determining the quality and resourcefulness of our coastal waters. Many of the few weaknesses that were identified among the constituent laboratories, including the inability to compete for federal funding, lack of infrastructural support for enhancing multi-media research and modeling as well as collaborations with university researchers, must be addressed at the Director and higher levels.

ARL and its component laboratories are a valuable asset to NOAA and the Nation. They have established clear focus areas and identified important new initiatives that merge their component strengths and fill critical roles within NOAA.