THE ATR STUDY

- **Sponsors:** George Singley, OASA(RDA) (original sponsor)
  Dick Chait
  Fenner Milton, OASA(RDA)

- **Members:**
  Dick Hartman, Chair
  Ron Swonger, Vice Chair
  David Fried
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  Chuck Malone
  Don Pihl
  Carol Nash, OASA(RDA), staff asst.
  Joe Swistak, TEC, staff asst.
  Bob Guenther, ARO, advisor

- **Sources:**

ARL	ARPA	Martin
ARO	Lincoln Lab	Raytheon
CECOM / NV	Navy	Westinghouse
CRREL	Air Force	Brown
MICOM	TEC	MIT
PEO Intelligence	OASA(RDA)	Panel members
PEO Tactical Missiles		Intelligence School
PM Comanche	PM IEW	DCSINT

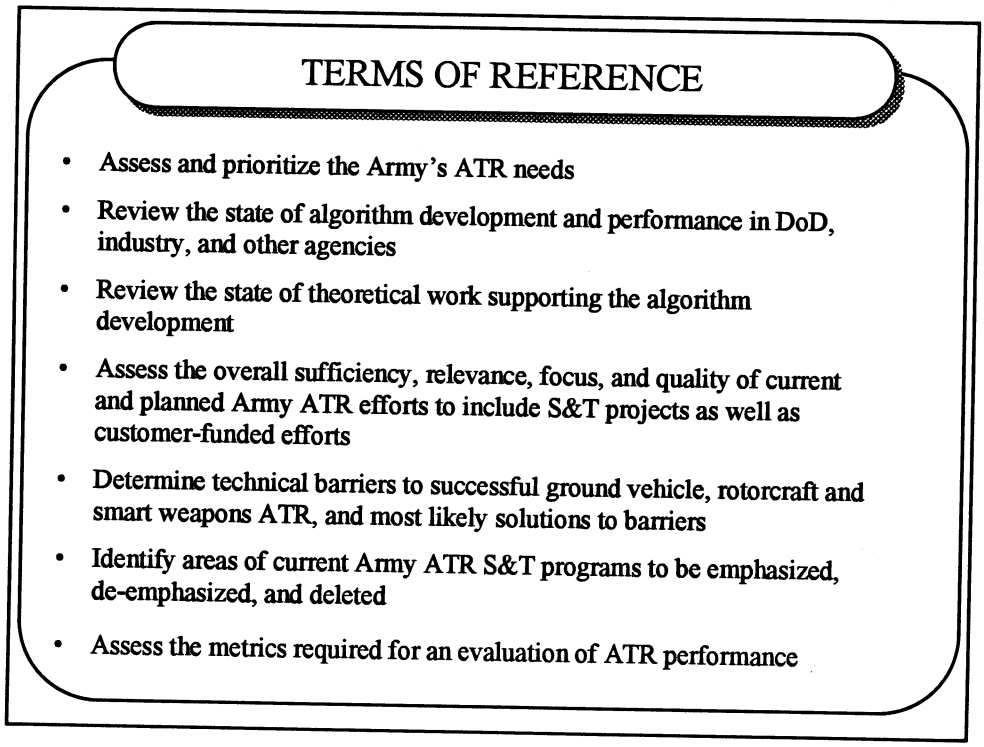
The Army Science Board (ASB) Ad Hoc Study, "Aided Target Recognition (ATR)," was briefed several times during its development. These briefings included in-progress reviews with the sponsor, the Deputy Assistant Secretary (Research and Technology) (DAS[R&T]), originally Mr. George Singley, and a final briefing to Dr. Richard Chait when he was the acting DAS(R&T). Dr. Fenner Milton, who later became the DAS(R&T), also participated in these briefings. The final briefing was delivered to an audience representing several Army institutions. Mr. Ron Swonger briefed the preliminary report to a working group from the Office of the Deputy Chief of Staff for Intelligence (ODCSINT) and to the ASB.

The Assistant Secretary of the Army (Research, Development and Acquisition) (ASA[RDA]) then appointed an in-house working group to develop an implementation plan for the Study's recommendations.

It is clear from these briefings that ATR is a controversial field. As evidenced in the following pages, the lack of quantification and standards makes judgments subjective. However, Panel members were well qualified to make such judgments.

The Panel attempted to deliver positive statements only in the briefings, and that is reflected in the slides contained herein. However, the Study Group encountered vocal objections to virtually every change it recommended, usually from those affected by the changes, even though they were presented as positive improvements rather than corrections of defects. (The Army Research Office [ARO] was a notable exception, responding to suggestions faster than the Panel could create the briefings.)

Therefore, in the text of this Report, the Panel has chosen to be more explicit about shortcomings it uncovered than were delivered in the briefings.



The Terms of Reference (TOR) were provided by the ASA(RDA), and were expanded by the ASB Chair.

The complete TOR is included as Appendix A of this Report.

SNAPSHOT: CONCLUSIONS VERSUS TOR

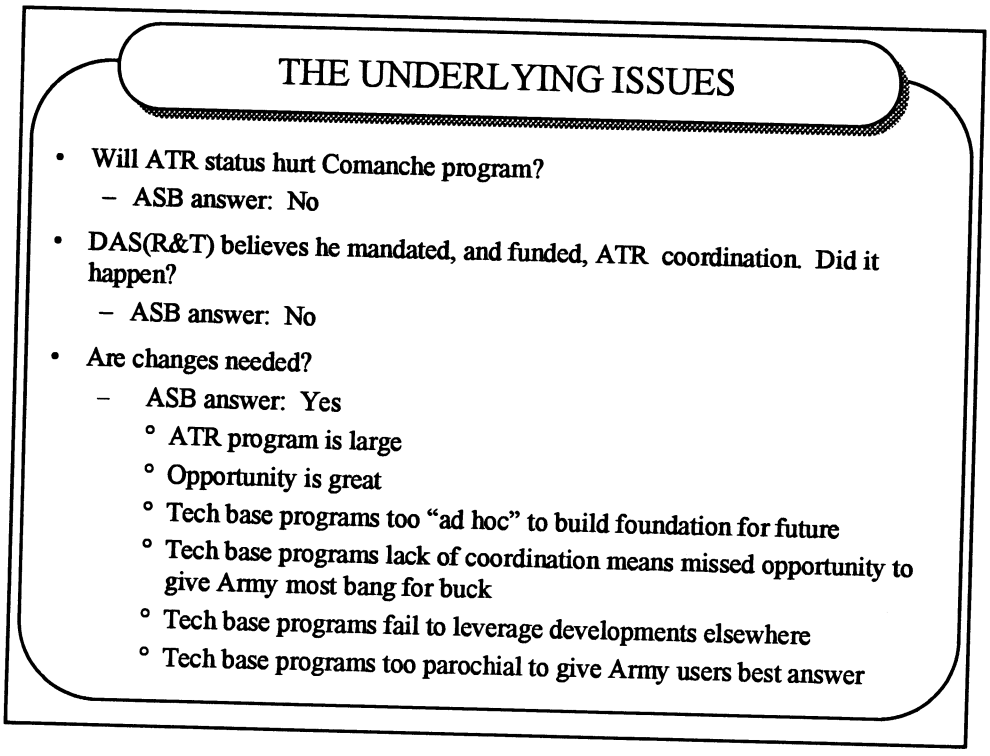
• Needs:	Comanche is the only formal requirement Many other systems waiting for "breakthroughs"
• Performance:	Meets Comanche requirements Crossing the threshold for other Army utility
• Theory:	Underpinnings poor
• Army efforts:	Project-related programs in good shape 6.1 and 6.2 programs insufficiently focused or coordinated
• Barriers:	No agreement on barriers Little Army S&T attention to identifying them
• S&T programs:	Panel recommends changing from a collection of ad hoc efforts to a "program"
• Metrics:	No common test conditions or metrics, little focus of metrics on prediction of Army utility

The Panel found ATR to be awash with controversy.

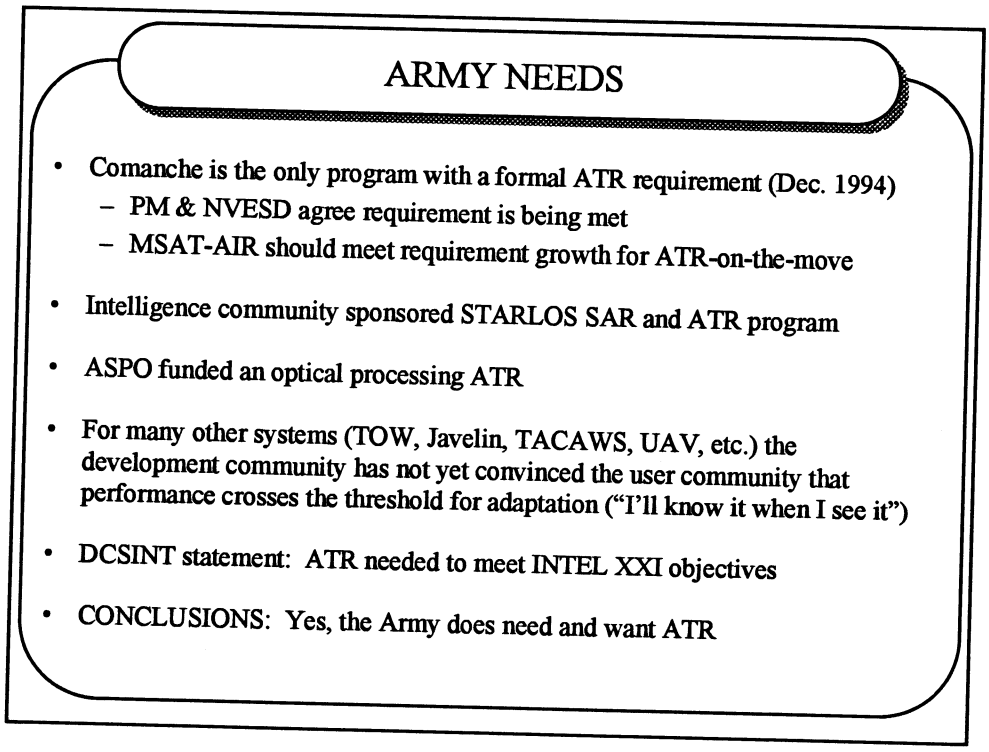
Many knowledgeable outsiders have asserted that ATR is on the far horizon. However, the Panel was pleasantly surprised at the near-term level of performance that has been achieved in a few cases; the Study will later discuss what has led to this.

Major progress has been limited to what the Study Group calls "project-related programs" in the above slide. These programs are Program Manager (PM)-funded, or 6.3 programs, with well-defined requirements that are being met. These programs include Comanche ATR, STARLOS, and MSAT-AIR. An Army Space Program Office (ASPO) program at the U.S. Army Missile Command (MICOM) was satisfying space requirements.

On the other hand, the 6.1 and 6.2 programs were disjointed, and were providing little or no critical input to the project-related programs. The Panel frequently heard 6.1 and 6.2 researchers assert that they were doing their work for program "X", but when the "X" office was queried about said program, it was found that they were usually not planning on using any results of that work, and in some cases did not even know about it. There were notable exceptions at the U.S. Army Communications-Electronics Command (CECOM) and MICOM, where some 6.1 and 6.2 programs had clear links to projects if successful.



The above slide shows the critical issues; they provide a different perspective than that of the TOR.



At the time of this Study, LTG(R) Donald Pihl conducted a broad survey of Army requirements, and found only one formal requirement—for a Comanche ATR.

A retired general stated that the Army needs ATR and has been waiting a long time for it. He believed that the Army had been disappointed in actual (versus promised) performance so many times that most users would not write it into requirements.

ATR COMPLEXITY

- Many applications: Intelligence, Reconnaissance, Target acquisition, IFF, Target servicing
- Many platforms: Comanche, Other helicopters, UAVs, Missiles, Space platforms, Armor
- Many sensors: E.O. sensors—visible, FLIR, laser radar; Radar sensors—SAR, real beam
- Many Technologies: Algorithms—many; Hardware—digital, optical, neural network
- Many Army Developers: ARO, ARL, CECOM-NVESD, Missile Command, CRREL, TEC, PM COMANCHE
- Many players in other Services, industry, and universities

There is no single ATR problem, or solution. When an individual states "ATR works," or "ATR doesn't work," it is an insufficient statement: the platform, sensor (even what generation of sensor) and application must be specified.

There is a portion of the ATR community which thinks "synthetic aperture radar (SAR)" when the word ATR is mentioned. At a recent Society of Photo-Optical and Instrumentation Engineers (SPIE) meeting, the sessions entitled "ATR" were all SAR. However, many forward-looking infrared radar (FLIR) papers which had ATR in the title were entitled "object recognition" or "image recognition" in sessions.

This is an important point: the Panel found that many disagreements on the status of ATR were really communication problems.

When a previous slide stated that Comanche ATR meets requirements, it is due to more than ATR developments. The total system has been designed around a reasonable expectation of ATR performance, and has merged the role of the operator, the platform, the sensor, and even tactics, to fit that expectation.

ATR STATUS: PERFORMANCE

- ATR is now good enough for the Army to use (see caveats!)
  - Contractor's FLIR ATR performance supports the Comanche requirement
  - STARLOS ATR supports potential surveillance needs
  - Multimode ATR, such as MSAT-Air, supports growth in Comanche requirements
- This status has developed in recent years
- Paradigm shift rather than "breakthrough"
  - Use high-resolution images (2nd Gen. FLIR, best SAR) instead of trying to recognize "blobs"
  - Take advantage of human operators through smart system integration
  - Use several complementary algorithms rather than trying for one miracle

As discussed in the next slide, the above assessment is subject to several caveats.

Presentations to the Panel were judged to vary from slightly conservative to extremely optimistic. Among the Panel members, there was a range of opinions regarding the status of each program. The above slide represents a majority opinion, and when put with the caveats on the next slide, perhaps even a unanimous opinion.

The paradigm shift is the critical factor! Comanche uses the best FLIR images. The images are combined with location and altitude information, along with digital maps, to provide slant range, and thus scale, to ground targets.

The Comanche requirement matches the achievable ATR performance with a gunner's station, which takes the best advantage of an individual's ability to discriminate targets from false alarms.

CAVEATS

- Not all COMANCHE / STARLOS claims have been subjected to independent government verification (Spring 1995)
  - However, contractor teams have credibility—past claims have been verified
- There are no common metrics used for assessment
- ASB Panel has no independent means of evaluation
- The systems have not been tried in a sufficiently broad range of scenarios
- The COMANCHE FLIR ATR range requirement seems at odds with the range requirements for weapon systems which will go on COMANCHE
- There are no miracles—if conditions are such that contrast goes to zero, no system will work (human or automatic)

The lack of quantified figures of merit-related-to-operational needs, compounded by the rare use of common imagery, means that the Panel's judgments are subjective.

FLAWS

- Everyone is selling his own approach to his (potential) customers
  - Developers are unaware of broad Army needs
  - Customers seem unaware of potential developments, other than those presented by their developers, or of needs outside their own mission areas
- No one is focused on increased understanding
- No one is focused on fundamental barriers to progress
- There are no common metrics or tests
- Cooperation between players is spotty. The problem is one of missed opportunity rather than unwarranted duplication
- Many 6.1 and 6.2 researchers are using unrealistic imagery, with no clutter
- These observations apply across DoD. Other programs, including ARPA's large investment, have the same flaws

The Panel heard comments similar to those above from many observers. The DCSINT team charged with looking at ATR for intelligence purposes rapidly arrived at similar conclusions. Several Army personnel involved in ATR highlighted these very flaws to the Panel; however, several others insisted that the flaws do not exist.

As examples:

- A MICOM briefer cited helicopter false alarm requirements which were in fact orders of magnitude above those in the formal Comanche requirement.

- An Army Research Laboratory (ARL) briefer insisted that his program was to improve Comanche ATR. He appeared to have no idea of the status of the Comanche contractor's ATR, which was in fact performing far better than the "improvement."

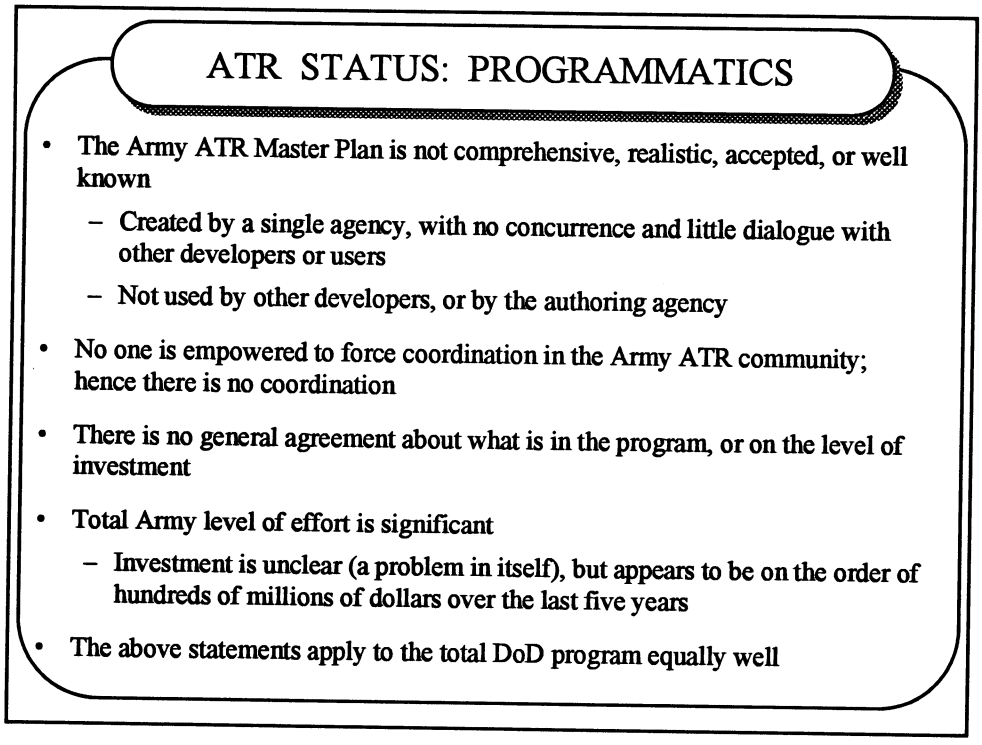
- ASPO is putting significant funds into far-out technology, without exposure to more mature developments which might satisfy its needs.

- No one knows the Army's ATR expenditure over five years to within one-quarter of a billion dollars.

- CECOM claims imagery is accessible; other developers say this is not so. In a test by the ASB, it actually took eighteen months, and attacks on major bureaucratic hurdles, to get a tape which is in a fairly unique format.

- The Army member of an existing "coordination" committee claims no more "coordination" is needed. But developers in other Research, Development and Engineering Centers (RDECs) say they have never been contacted by the Army coordinator.

- A quick look by non-ATR experts in ODCSINT concluded that the lack of coordination was glaringly obvious.



Although the finding in the above slide was extremely controversial, the Panel stands by it. Mr. Singley believed that he had charged, and funded, ARL with the task of creating an ATR master plan. ARL representatives have insisted that they never understood the charge to be explicit or continuous. It is outside the charter of this Panel to resolve such a dispute.

Regardless of intention, these findings about the master plan are valid. The RDECs contend that they requested data for the plan, but never had a chance to comment on the plan itself. They find the master plan to be of no use in planning their ATR programs. The Panel had difficulty at ARL obtaining information about the master plan, and found little evidence that ARL was utilizing it.

There was no concurrence throughout the Army on the level of effort in the Army program. It is true that it is difficult or impossible to separate sensor, platform, and ATR costs. Nevertheless, two independent attempts to access data bases to determine the size of the ATR program revealed that costs were above a quarter of a billion dollars over five years (leading up to 1994). Even if this is not true, anyone else assessing the data bases will come away with a similar conclusion.

It is critical to note that these shortcomings are not the uniquely the Army's, but are present in the field as a whole; for instance, the Defense Advanced Research Projects Agency's (DARPA) programs appeared disjointed as well.

OBSERVATIONS ABOUT THE ARMY'S ATR EFFORTS

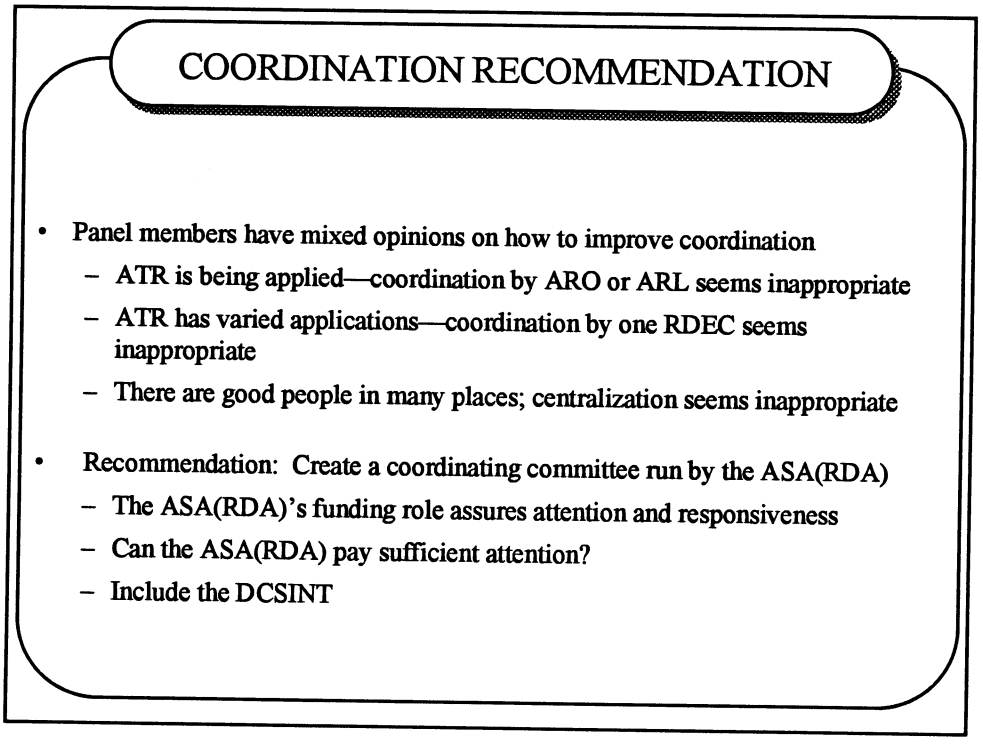
- EVERYONE: Good people trying to do a good job, but there is no team.
- ARO: Past program was not fundamental; very responsive in starting new fundamental effort.
- ARL: Program varies from excellent in SAR ATR, to "me too" in 6.1/6.2. There is a major opportunity to focus on "leap-ahead" technologies.
- CECOM/NVESD: Appropriately focused on applications to helicopters. Technology base supports applications, and has broader value.
- MICOM: Focused on customer-funded applications in missiles and space. Technology base supports applications, and has broader value.
- CRREL: Providing imagery data base, with good focus on distributing data, but it is unclear why CRREL is a player in this field.

There is some good work ongoing in the ATR field; there is much ad hoc algorithm development. However, the underlying theme to the Panel's findings is that there is no Army "team."

KEY RECOMMENDATIONS

- Begin a program at ARO to develop fundamental underpinnings
- Encourage (force?) the community to establish common metrics
- Encourage (force?) algorithm developers to use realistic Army scenes, especially involving clutter
- Redirect a portion of the ARL program toward identification of barriers, and overcoming them
- Refine allocation of Army resources
- Improve and empower coordination of all Army ATR investments through an Army Science and Technology Working Group panel co-chaired by representatives of the DCSINT and the ASA(RDA)

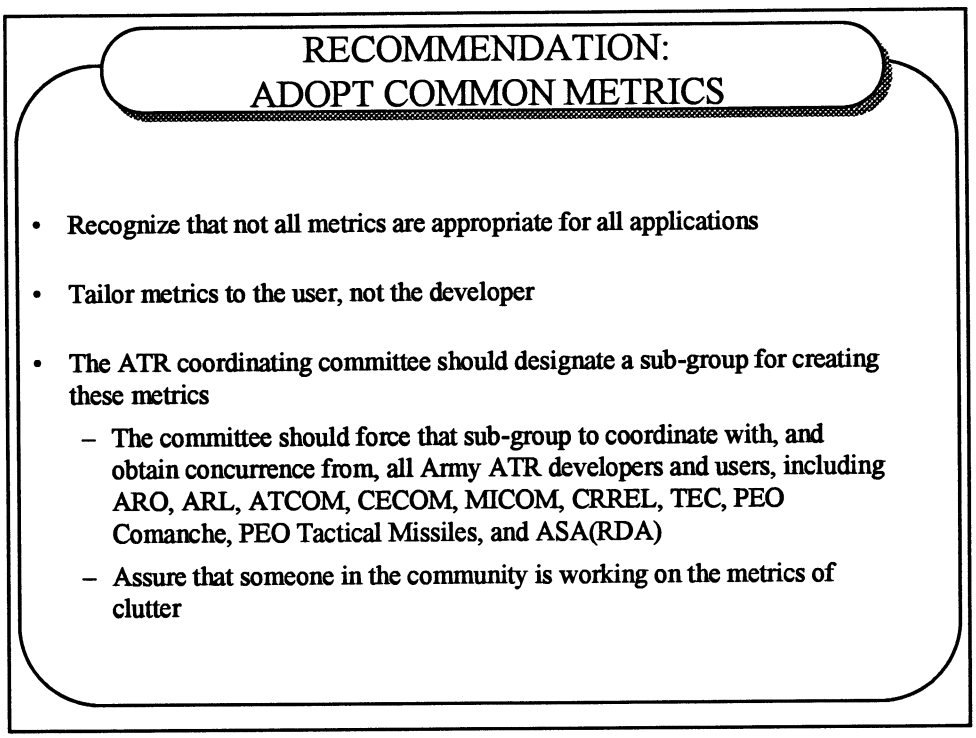
The Panel's recommendations were discussed with Mr. Singley, and refined to make them actionable within his authority. It has been apparent that his successors, in turn, have different preferences as to how to implement these recommendations. Those differences have not been incorporated into this Report.



At the In-Progress Review (IPR), Mr. Singley's reaction was that the coordination group should be a working panel of the ATSWG. At the time of the final briefing, staffing in OASA(RDA) was in a state of flux.

Before leaving, Mr. Singley indicated that including ODCSINT in the coordination was a desired move; however, there were several unresolved issues. ODCSINT appeared to be relying on the Program Executive Officer for Intelligence and Electronic Warfare (PEO/IEW) for support of this role, but the PEO reports to OASA(RDA), not ODCSINT. Many of the programs are in the tech base, and others such as Comanche do not fall under the purview of the PEO/IEW.

It is the Panel's understanding that a committee appointed by Dr. Milton to study the implementation of this Study's recommendations is striving to define a coordination mechanism which meets needs.



Metrics are sadly lacking. Only at Lincoln Laboratories did Panel members hear a consistent set of metrics across several briefings.

It is critical that metrics be of value to the user. The user must be able to predict the performance of future systems which use ATR, and metrics must be suitable for those predictions.

Above all else, metrics on clutter are lacking. This is not a case of agreeing on common metrics—some effort is required in their development.

RECOMMENDATION: STRENGTHEN THE FOUNDATIONS OF ATR SCIENCE

- Focus researchers upon key fundamental problems relating to ATR via more specific BAA's
- Involve the physics and engineering organizations of ARO in the solicitation of ATR research grants
- Educate the academic researchers in physical and other realities and constraints of the ATR problem environment
- Develop guidelines for adequate ATR research, experimental, and analytic methodologies
- Collect and disseminate an ATR research tool kit to facilitate meaningful and productive research. Insist upon its use.
- Combine and compare component research results, where feasible, with more comprehensive results, which will be facilitated through the use of the above guidelines and tool kit

The Panel concluded that ARO is an appropriate organization to pursue an improved understanding of ATR fundamentals, and offers the above guidelines.

Since this Report was first briefed, ARO has undertaken a program in response to this recommendation.

RECOMMENDATION: IMAGERY

- The ASTWG ATR panel should designate a sub-group to develop a set of common image data bases which can used with the metrics.
- Use good, realistic imagery. It is pointless to use ATR with imagery from systems so old and poor the Army would not have then in the field.
- Make those data bases available throughout the ATR community!
- Encourage the use of this realistic data base by:
  - Making it available to all contractors, including universities
  - Evaluate progress not only on metrics, but on the movement toward realistic imagery. Recognizing the letter "E" may be acceptable in the first quarter of a program, but not thereafter.

A universal complaint from workers in the field (except at CECOM/Night Vision and Electronic Sensors Directorate [NVESD]) was the lack of realistic infrared (IR) imagery. CECOM/NVESD claimed that the imagery was readily available. The Panel found that this was not the case.

Some researchers working with FLIR imagery are using poor representations of first-generation FLIRs. This is unrealistic: by the time systems using ATR are in the field, they will be using second-generation FLIRs. Synergistically, these provide imagery which is easier to recognize.

A large number of researchers in 6.1 and 6.2 programs are looking at pristine figures (such as the letter "E", or the outline of a tank), with no clutter in the scene. While there is a role for this in early development, researchers need to start examining realistic, cluttered scenes.

RECOMMENDATION: REFOCUS ATR AT ARL

- Establish and implement an effort to identify common technical barriers to improved ATR performance
- Baseline on best current performance: Comanche, MSAT, MUSTARS, STARLOS
- Work until the product is believed by the RDECs (CECOM, MICOM, ATCOM), PM Comanche, and PM IEW
- Identify important but unexploited technical opportunities
  - Context
  - Time history
  - Others
- Put together a plan which refocuses ARL's efforts along the dimensions of common technical barriers and unexploited technical opportunities

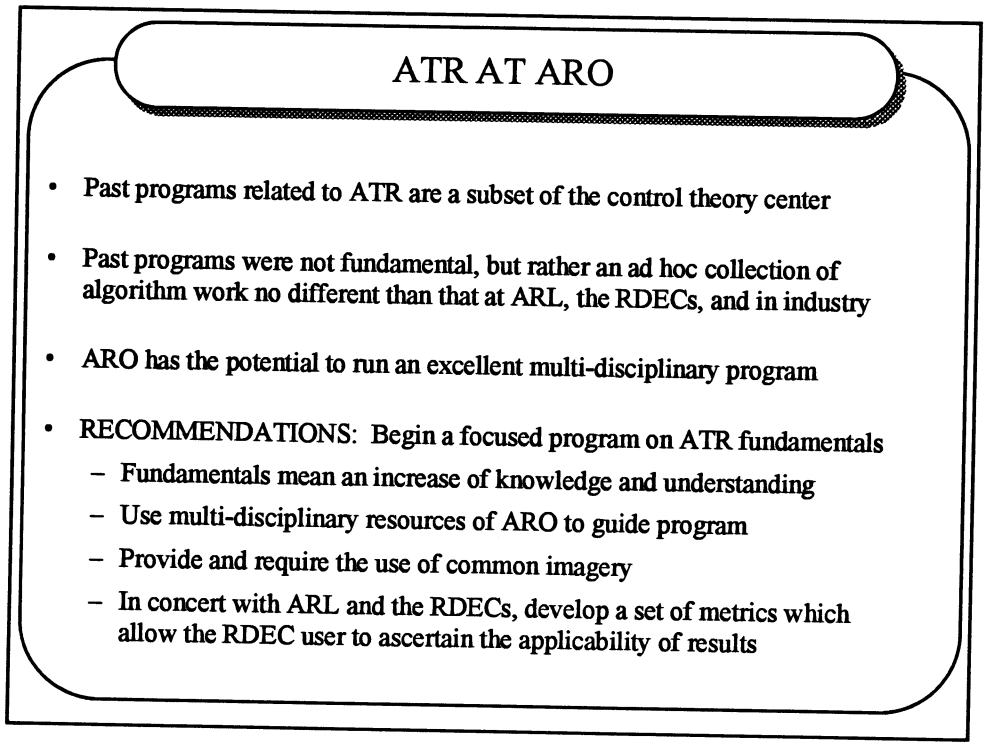
The Panel found that work on FLIR ATR at ARL, the RDECs, universities, and in the DARPA program was primarily a collection of ad hoc algorithms, with nothing to indicate any superiority.

The Study Group also found that there was little Army activity attempting to identify barriers to overall progress.

The Panel found little activity (except at MICOM) to step outside the conventional bounds of ATR algorithm development (e.g., to exploit contextual information like human analysts, or time histories like human observers).

Of all the entities involved in in-house research, ARL has the charter for far-reaching, across-the-board research.

Therefore, the Panel concluded that ARL should refocus its program as described in the above slide.



The Panel found ARO to be pursuing a similar ad hoc collection of algorithm development relative to ATR. However, ARO was extremely responsive to concerns raised by the Study, and initiated a new program in image science during the course of the Study.

ATR AT ARL

- STARLOS, an SAR program, is healthy.
- ARL could better exploit its unique role in the Army R&D community:
  - Technology base program is similar to all others'—an ad hoc collection of algorithms.
  - ARL's program is no more fundamental, broad-reaching, or leap-ahead than the RDEC programs.
  - Although many programs are justified on the basis of system applications, they are not (probably cannot and should not be) as well focused on the user as those of the RDECs.
- ARL is making strides toward improved interfaces with the RDECs, but the general reaction is one of tolerance rather than dependence. Many RDEC researchers, given a choice, would use the investment represented by ARL TRPs elsewhere. The RDECs are not relying on ARL for critical tasks.

ATR at ARL, in 6.1 and 6.2, is viewed with suspicion by the RDECs. The entire role of ARL vis-à-vis the RDECs is complicated and evolving, and ATR is just one facet of that relationship.

ARL cited several Technology Planning Annexes (TPAs) as evidence of its close links with the RDECs. The RDECs acknowledged the existence of these TPAs; however, RDEC managers were not putting ARL tasks on the critical path to success. When asked if the ARL TPA task was the most important funding consideration, RDEC technical managers universally said no. (The question was phrased so that obtaining in-house funds was not an option.)

One RDEC PM said ARL 'talked a very good story in support,' but did not deliver a product—they were batting 0-for-5 in his eyes.

ATR AT CECOM/NVESD

- Well-linked with its principal customer, Comanche
- Well-tuned to industrial developments
- Responsible for the primary attempts at government baselining and evaluation, and at comparison of multiple approaches
- Imperfectly linked to developments at other centers and the needs of other potential customers
- Unresolved problem in sharing of imagery
- Except for a role in increased Army coordination, no refocusing or fine tuning suggested

CECOM/NVESD is a major player in ATR with FLIR and millimeter wave radar. The Panel does not recommend any changes to the CECOM/NVESD program.

ATR AT MICOM

- Focused on missile and space applications, but there is some "blue sky" research
- Wide range of customer-funded programs
- Loss of 6.1 funds hurts
- Much potential use: TACAWS, EFOG-M, UAV, space systems
- End users are eagerly awaiting performance sufficient to support the establishment of formal requirements
- RECOMMENDATIONS:
  - Continue system and customer focus
  - Pay more attention to representing the capabilities of the entire ATR world to customers, rather than just an engineer's "pet" program

MICOM is pursuing ATR for weapon systems. While aided target recognition will help many systems, such as FOG-M, MICOM is the prime player in automatic target recognition.

The Panel was unable to get a clear picture of funding profiles. MICOM was losing 6.1 funds during the course of this Study, yet was perhaps conducting the most far-reaching research of any of the in-house laboratories. There was an indication that one of these programs was going to receive major funding from ASPO; in fact, that potential investment appeared excessively large. However, the Panel did not study such customer-funded programs.