En Route Problem Detection and Resolution - Research Prototypes and Process

FAA/NASA JUP Quarterly Review

April 6, 2001

F042-B-001

Overview

- **The research problem**
  - **Support strategic problem solving and planning at the enroute air traffic control sector**
    - **Flight Data Management, Problem Detection and Resolution**
- **The application prototypes**
  - **Initial laboratory research**
    - **Automated En Route ATC (AERA)**
  - **Problem Detection and Flight Data Management development**
    - **User Request Evaluation Tool (URET)**
  - **Problem Resolution**
    - **Problem Analysis, Resolution and Ranking (PARR)**

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Overview (concluded)

- Research objectives
- The research process and lessons learned
  - AERA 2 Development and observations
  - URET Evaluation evolution and lessons learned
  - PARR Evaluations
- Some candidate areas for additional research

The Research Problem

- **Airspace user needs**
  - **More flexibility**
  - **Choice of route, altitude, speed profiles**
- **Reduced structure results in more complex aircraft encounters**
- **Controllers need decision support systems**
  - **to accommodate user preferences**
  - **to handle more complex situations**

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Automated En Route ATC (AERA)

- **Project spanned 1977 - 1994; a component of the Advanced Automation System (AAS)**
- **Intensive laboratory evals with FAA controller teams starting in the late 1980s**
- **Three components:**
  - **AERA 1: Integrated R&D-side Conflict Probe**
  - **AERA 2: Enhancements including Automated Problem Resolution and new data-link capabilities**
  - **AERA 3: Routine separation handled by the automation; Controller becomes airspace manager**

URET

- **URET is a set of conflict probe and flight data management tools**
  - **Based on AERA research**
  - **Designed to support strategic problem solving and planning at the enroute air traffic control sector**
  - **20 minute look-ahead for current and trial flight plan problems (40 minutes for restricted airspace problems)**
  - **“Send Amendment” 2-way host communication**
  - **Flight data management tools necessary to support operation with reduced flight strips**

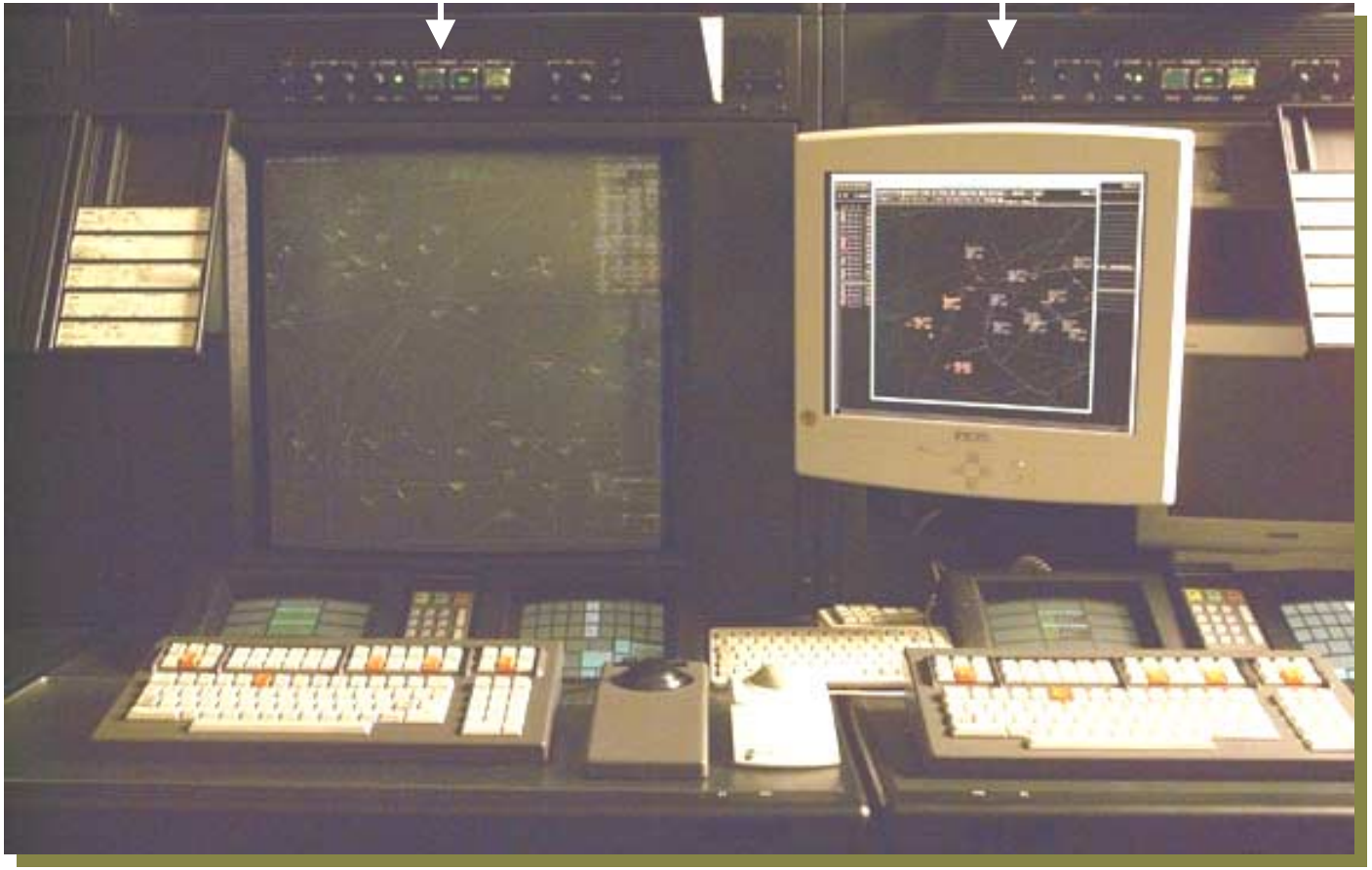
URET Prototype

- **URET Prototype mission:**
  - **Prototype and evaluate an operationally reasonable and beneficial subset of AERA capabilities in the field**
  - **Reduce the risk in the acquisition of URET Core Capabilities Limited Deployment (CCLD)**
- **URET Prototype currently in 22x7 operation Daily Use at the Indianapolis and Memphis Air Route Traffic Control Centers (ARTCCs)**
  - **> 800 operational personnel trained**
  - **> 900,000 sector hours of operation**

URET Prototype (Concluded)

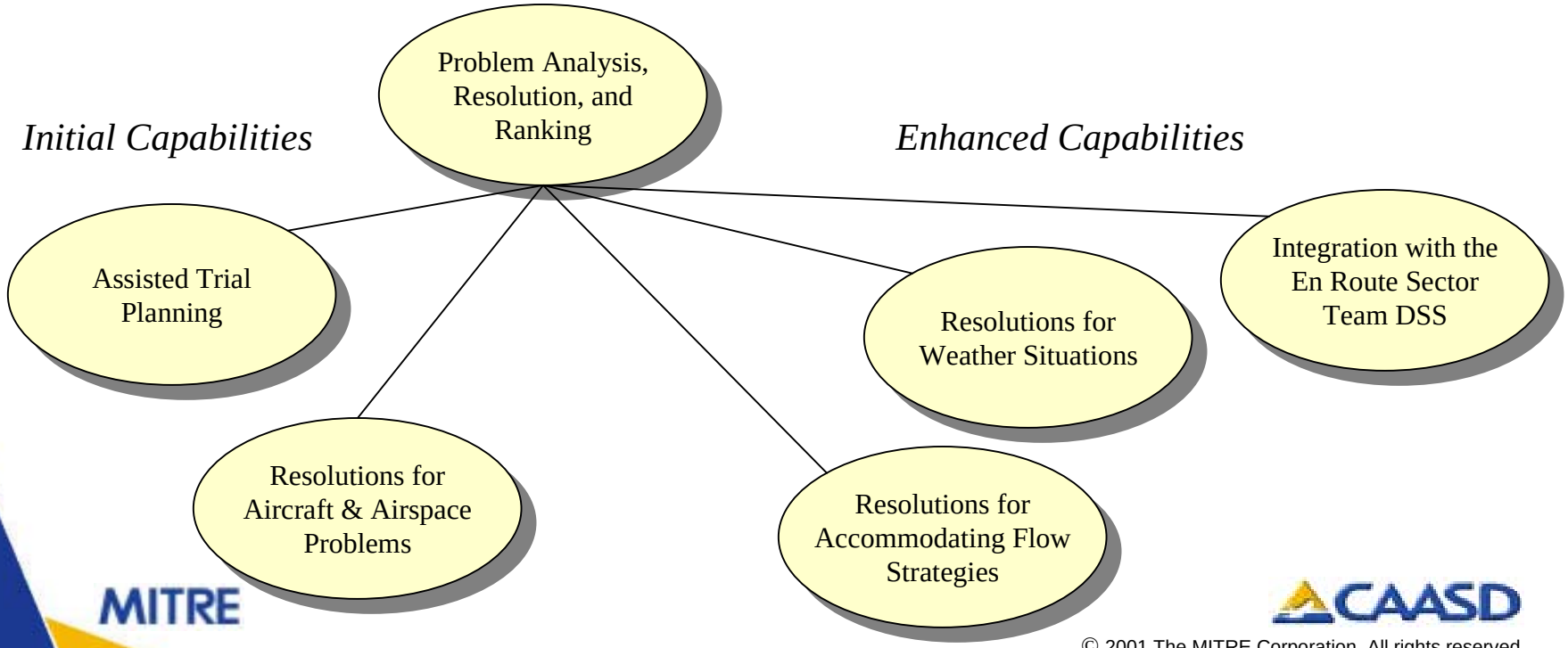
R-Side
DSR (Display System Replacement)

D-Side
URET Prototype



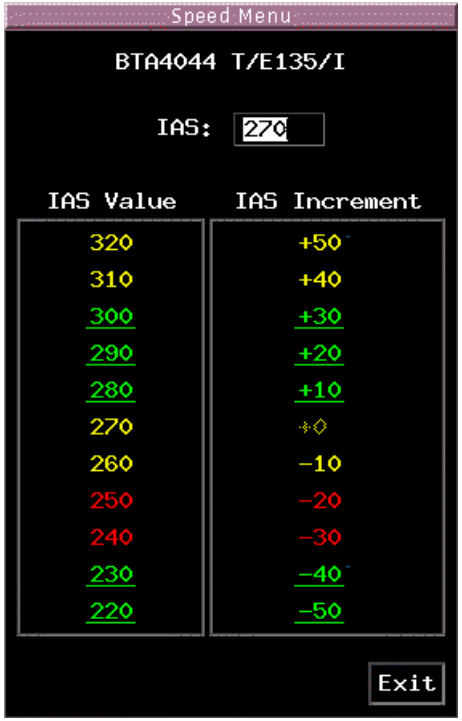
What is PARR?

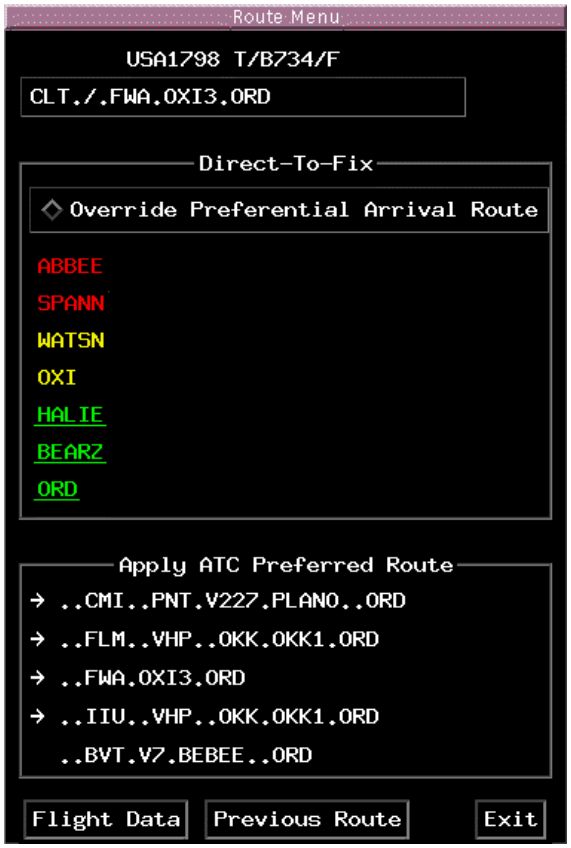
- **PARR is a resolution capability defined as Priority Research for FFP2, supporting goals of:**
  - **Enhanced safety, reduced sector workload, increased user benefits, enhanced probe accuracy**



PARR Initial Capabilities
Assisted Trial Planning

- **Color-coding of URET menu entries with probe results**
- **Similar to AERA Quick Trial Planning**





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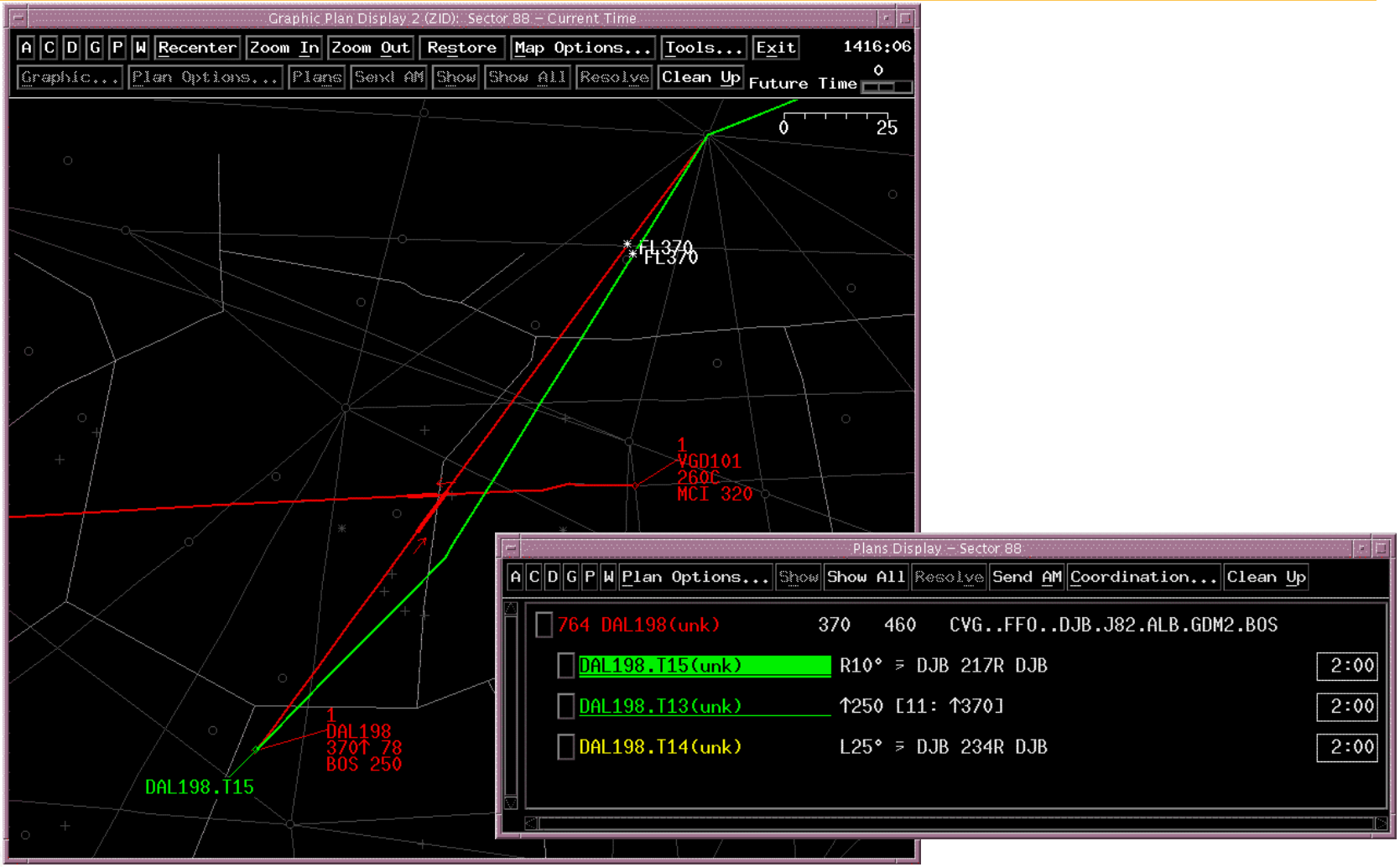
PARR Initial Capabilities
Resolutions for Aircraft & Airspace Problems

- **Based on AERA Research (1977 - 1994)**
- **Continuation of URET Evolution (1994 - now)**
  - **Uses all URET functional building blocks**
    - **Trajectory modeling, conflict detection, CHI**
  - **Searches for efficient, conflict-free Trial Plans**
- **Controller initiated, either**
  - **For an aircraft (maneuver only that aircraft)**
  - **For a problem (maneuver either involved aircraft)**
  - **Up to 5 resolutions per aircraft**
    - **2 Lateral, 2 Altitude (left/right/above/below conflict)**
    - **1 Speed change (either increase or decrease)**
- **Resulting resolutions are ranked for display**

PARR Initial Capabilities
Aircraft Problem Resolution Illustration



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Research Objectives

- **Field and evaluate a sufficiently robust, mature conflict probe prototype to**
  - **Demonstrate and complete development of the operational concept**
  - **Develop details of the operational and technical requirements needed for expanded use and wider deployment**
  - **Reduce acquisition risk**
- **Demonstrate potential benefits to the National Airspace System (NAS)**

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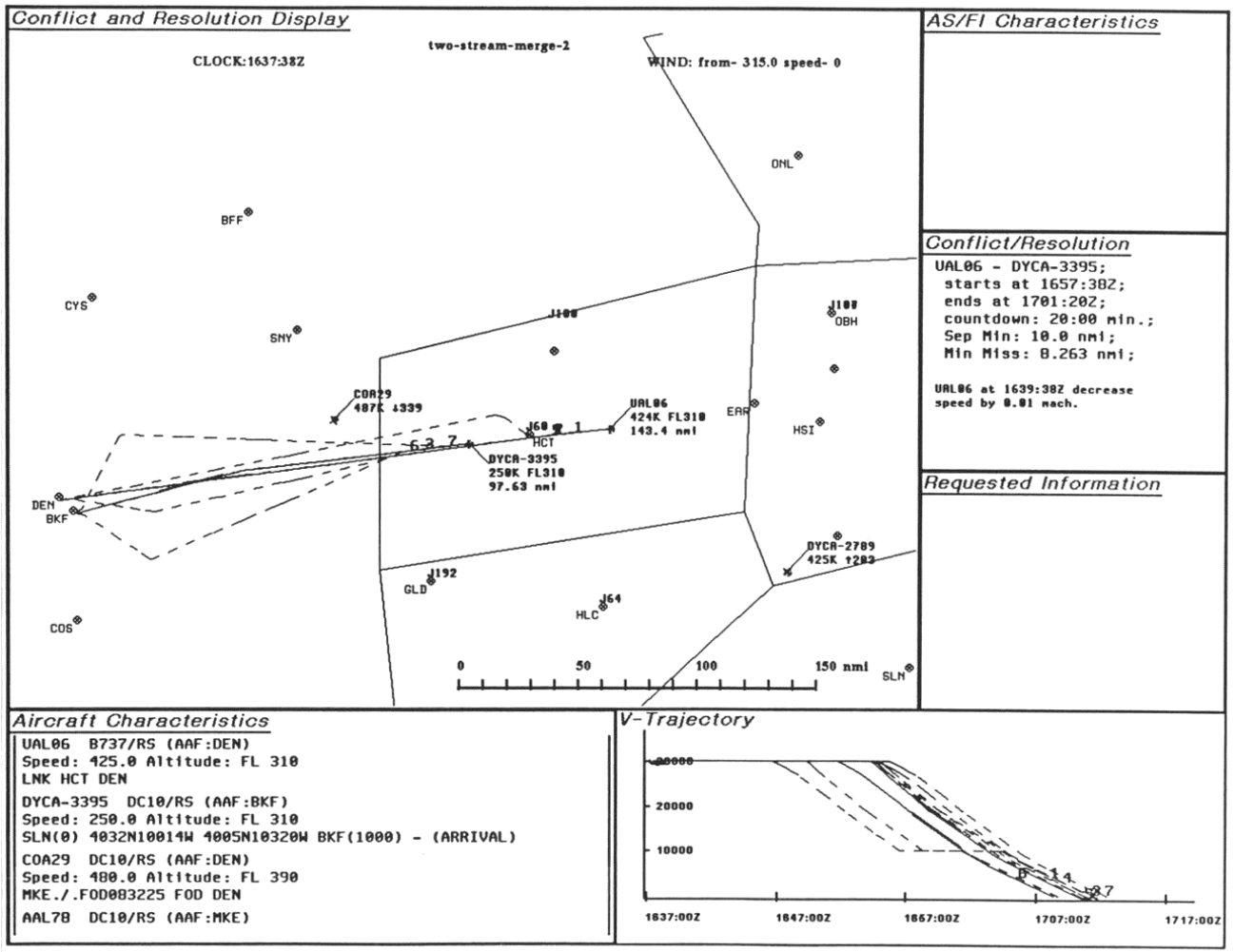
AERA 2 Development (1987 - 1994)

- **AERA Controller Team assembled for AERA 2 laboratory evaluations**
- **Part of Advanced Automation System (AAS) acquisition**
- **Development of AERA 2 System Level, CHI and Algorithmic Specifications**

AERA 2 Development
Problem resolution prototype evaluation

Laboratory evaluations 3 - 4 times a year

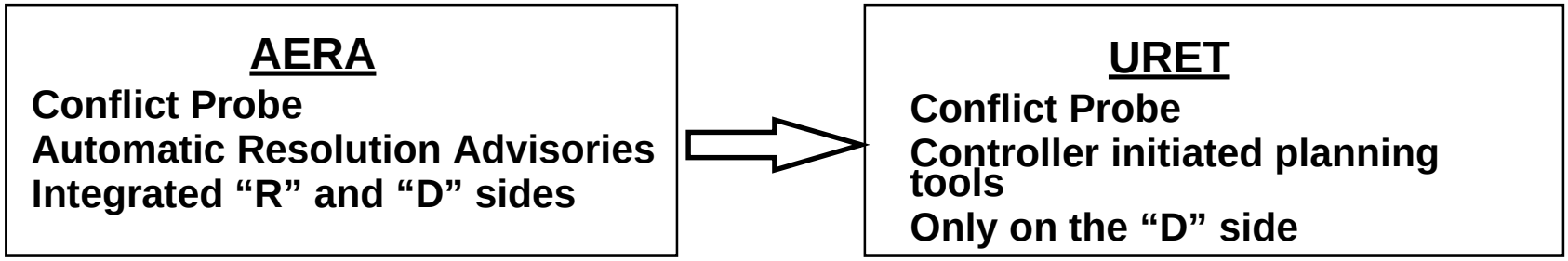


AERA 2 Development
CHI Prototyping

Some Observations from AERA Evaluations

- Maneuvers should be complete
- A set of resolutions in different dimensions and directions is needed, since
  - The system cannot anticipate all operational considerations
  - Application of rules to select dimensions/directions may miss good maneuvers
- Resolution ranking is important, but difficult
- A problem resolution function is critical to a fully strategic operation, where
  - Alerts go to the sector controlling the aircraft
  - Controlling sector solves downstream sector conflicts

The URET Development Challenge



- **Develop prototype of D-Side conflict probe and planning capabilities for operational evaluation**
  - **Capitalize on AERA work**
  - **"Get out of the lab and into the field"**
  - **Facilitate the transition from current ATC constructs and concepts toward a less constrained operational system**
- **Define training and evaluation program and prepare field personnel to participate**
- **Carry out evaluations and analyze data**

URET Evaluation Evolution

- **Original Mandate 1/95:**
  - **D-Side User Request Evaluation Tool and a Field Trial to start within one year at Indianapolis (ZID)**
- **URET evaluations began at ZID 1/96, ZME (Memphis) 6/97**
- **Evaluations with live traffic and controller operators**
  - **Initially "on the cart" operated by a 3rd controller**
  - **Then on the cart operated by the sector "D" controller**
    - **Flight Strips maintained by the sector controller**
  - **Then installed in the D position at selected M1 consoles**
    - **Consoles modified to install URET display**
    - **Flight Strips removed during evaluation**

URET Evaluation Evolution (Concluded)

- **"Daily Use" began 9/97 (ZID), 11/97 (ZME)**
- **Transition to DSR Control Room 11/99 - 3/00**
- **22 x 7 operations, all sectors 2/00**
- **As of Feb. 2001**
  - **> 900,000 hours sector hours of operation**
  - **> 300 operation personnel trained**

URET Lesson's Learned:
System Development

- **Conduct research in the field; maintain continuous operational input**
  - **Focus evaluations on operational requirements**
    - **Foster field advocacy early**
- **Move forward in small, well defined steps**
  - **Evolutionary development**
- **Establish benefits and metrics analysis program early**
- **Be part of the development team - Represent operational requirements and understand development constraints**

URET Lesson's Learned:
Evaluation and Concept Development

- **Conduct evaluations in an operational context**
  - **Live traffic**
  - **Realistic sector operations**
  - **Variety**
- **Understand the operational environment**
- **Focus evaluation on operational requirements (not just what they want but why they want it)**
- **Translate operational requirements into system and CHI requirements**
- **Develop a detailed operational concept to drive definition of functionality, design of CHI, and definition of training and evaluation**

URET Lesson's Learned: *"Daily Use"*

- **Use of the system will evolve and change (use is different from evaluation)**
  - **You can't learn everything in a structured evaluation**
  - **Controllers will use the system in unexpected ways**
  - **This does not mean evaluation results are invalid**
- **Continue to "evaluate" in Daily Use using a process to collect feedback from operation**
  - **Maintain communication with field to assure that you are processing feedback**

PARR Initial Capabilities – *Evaluation Overview*

- **PARR evaluations are focused on**
  - **Concept of Use development**
  - **Operational Acceptability assessment**
  - **Implementation Evolution definition**
- **2 recent evaluations have been conducted with operational personnel**
  - **August 2000 - In the CAASD Lab with Air Traffic Controllers from Indianapolis and Memphis ARTCCs**
  - **January 2001 - At the Indianapolis ARTCC With Air Traffic Controllers**

PARR August Evaluation

- **An initial lab evaluation conducted to address general concept and operational use issues**
  - **Initial validation and refinement of PARR Concept of Use**
  - **Definition of PARR's integration into strategic problem detection and planning operations at the enroute sector**
  - **Initial assessment of acceptability and usability of resolutions**
- **Operated the prototype running against recorded traffic**

PARR August Evaluation (Concluded)

- **Following operation, the controllers discussed and provided feedback to specific evaluation questions**
- **Feedback from this evaluation strengthened the concept of use and set the stage for the next evaluation conducted in the field**
- **Feedback included:**
  - **Information about acceptability of specific resolutions and resolution types**
  - **Techniques for controller use and coordination of resolutions**
  - **Initial information about "packaging" of PARR features for incremental implementation**

PARR January Evaluation

- First PARR field evaluation conducted January 23rd and 24th at Indianapolis ARTCC (ZID)
- ZID controllers evaluated the prototype in the URET training lab and the DYSIM Lab
  - Controllers received training and operated the prototype running recordings of traffic from ZID and running live traffic
  - DYSIM Lab provided an overall higher level of operational fidelity and an operational sector context in which to explore coordination within the sector team and across sectors

PARR January Evaluation Issues

- **Issue themes were the same as the August evaluation but questions were more specific and detailed**
- **Concept of use validation, and acceptability and usability of resolutions and ranking**
  - **When and for which problems PARR is most useful**
  - **Acceptability of resolution types**
  - **Usability to solve URET detected problems**
  - **Coordination of resolutions**
- **Incremental implementation**

PARR January Evaluation Feedback

- **Overall evaluation feedback was very positive**
  - **Based on this initial exposure the controllers felt that PARR provides usable resolutions**
    - **Resolutions can be implemented to solve problems the D-side would address**
    - **Resolutions provide more information about the problem and support decision making**
  - **PARR probed route, altitude and speed menus and notification were perceived to be immediately useful, beneficial, and applicable in current operations**
  - **More complex resolution maneuvers need additional evaluation, e.g., to study coordination between sectors**
- **Next evals planned for May**

Potential Areas for Additional Research

- **Maneuver construction**
  - **Techniques include**
    - **Genetic algorithms, control theory, iterative optimization techniques (e.g., linear and quadratic programming), potential fields, neural nets, relative motion geometry**
  - **For a given problem, generation of multiple aircraft maneuvers, and multiple dimension maneuvers**
  - **Determination of an optimal, coordinated set resolutions for all problems**
    - **Parallel processing approaches**
    - **Objective function**
  - **Aircraft self-separation algorithms**
  - **Determination when aircraft self-separation is appropriate**

Potential Areas for Additional Research (Concluded)

- System test and validation
  - Exhaustive search comparison
- Software verification methodologies
  - Particularly important for autonomous application
- Airspace complexity metrics, e.g., to
  - Avoid areas of high traffic complexity
  - Quantify resolution and system performance as a function of complexity
- Controller workload metrics
- System-wide simulation capabilities
  - Interaction between ground and air conflict resolution systems