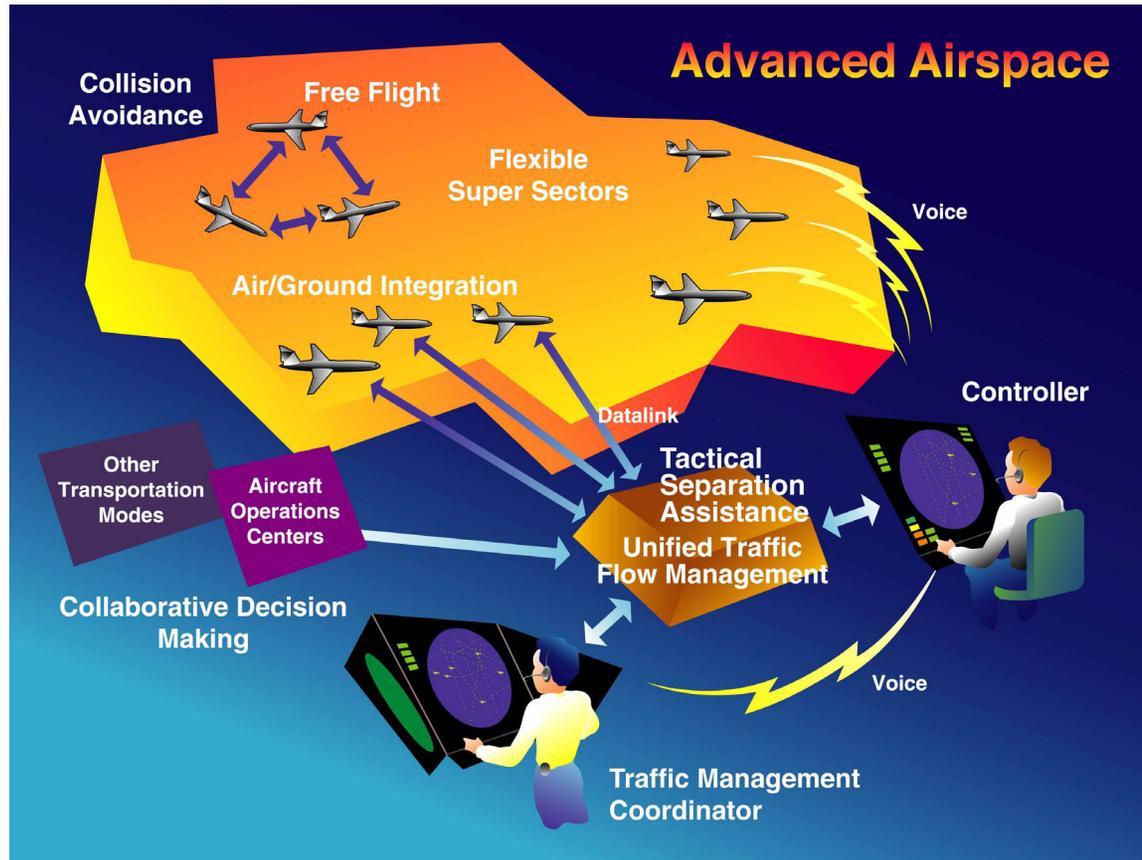


Advanced Airspace Concept



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by

Heinz Erzberger

Senior Scientist, Ames Research Center

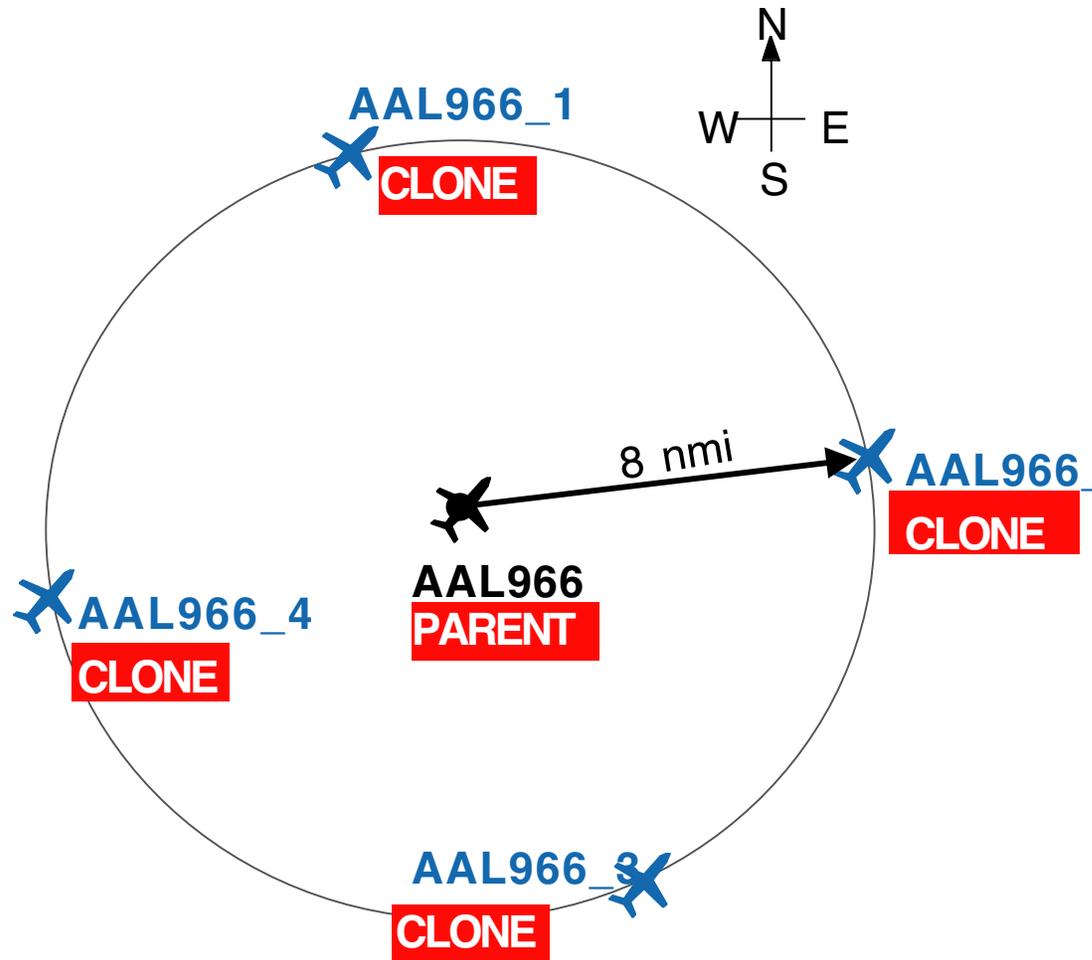
Overview

- Limitations of the existing system
- The **A**dvanced **A**irspace **C**oncept
- Candidate architecture for the **AAC**
- Separation assurance and conflict avoidance system (TSAFE)
- Ground-Air Interactions

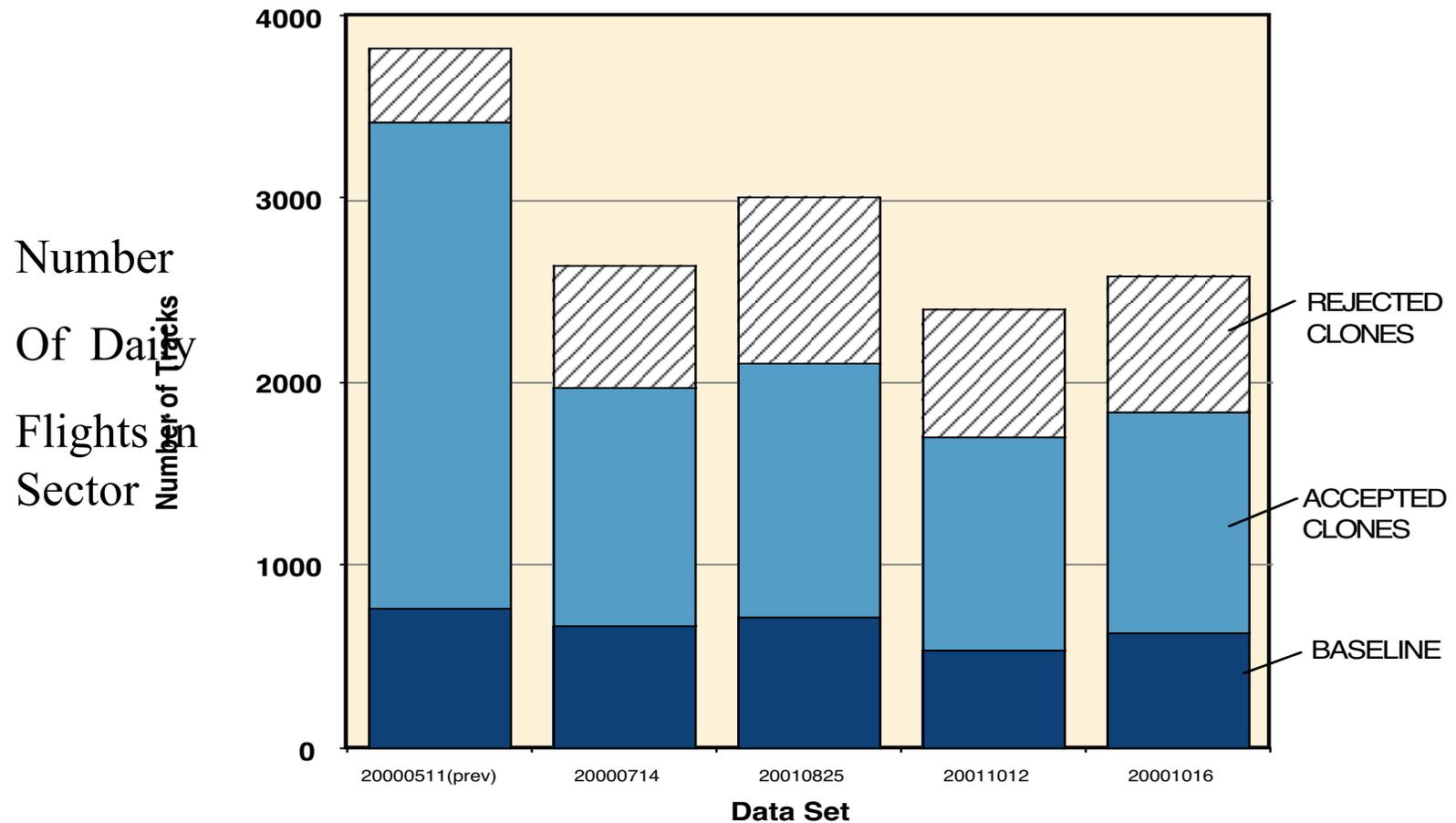
Limitations of the Current Paradigm

- Controller workload limits growth in sector capacity and throughput.
- Capacity gains through resectorization and sector size reduction have reached the point of diminishing returns.
- Decision Support Tools provide some improvements but can't circumvent basic controller workload limits.
- Manual monitoring and control of separations is subject to human error (FAA reports 50% jump in operational errors in 2000).

Cloning Method for Estimating En Route Airspace Capacity Potential



Results of Cloning Experiments



Advanced Airspace Concept has potential to more than double base line capacity

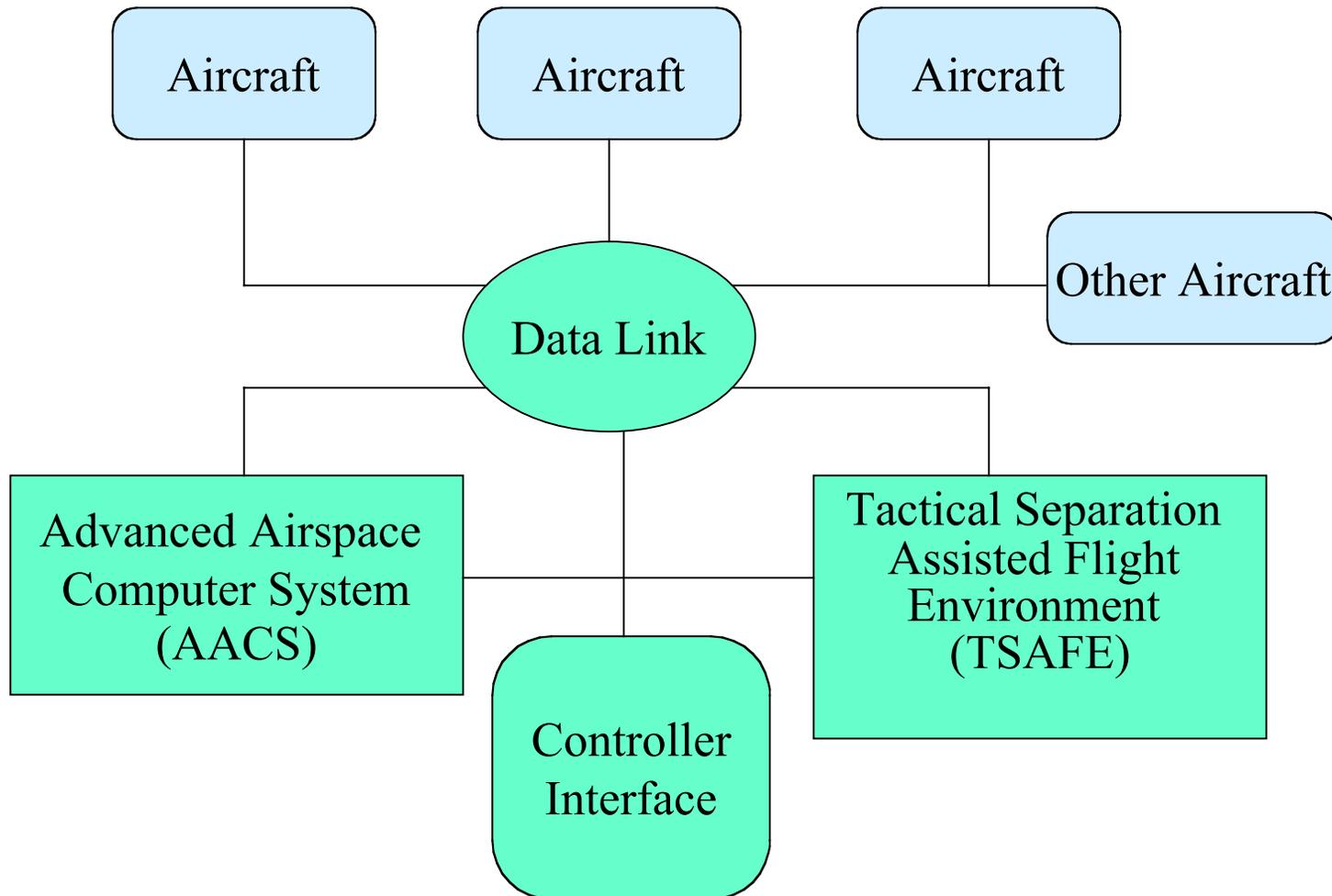
Overview of Advanced Airspace Concept

- Ground-based system generates 4D trajectories and separation assurance advisories for equipped aircraft
- Pilots, with the aid of Flight Management Systems, fly trajectories and advisories, which are sent to aircraft via data link.
- Ground and on-board systems help pilots maintain separation and safe operation in the event of certain types of failures
- Advanced Airspace sectors consist of several conventional sectors combined into super-sectors
- Voice communications between controller and pilots are available to handle unequipped aircraft, special pilot request, emergencies, loss of data link, etc.

Design Guidelines

- Utilize existing and planned infrastructure and operational systems
 - Mode S, ADS-B, GPS, Advanced FMS, Decision Support Tools, Data Link
- Keep on-board equipment requirements to a minimum
 - Data link and cockpit traffic display are essential
 - FMS highly desirable
- Provide safety net for specified failures
- Allow for transition from current operations to Advanced Airspace operations

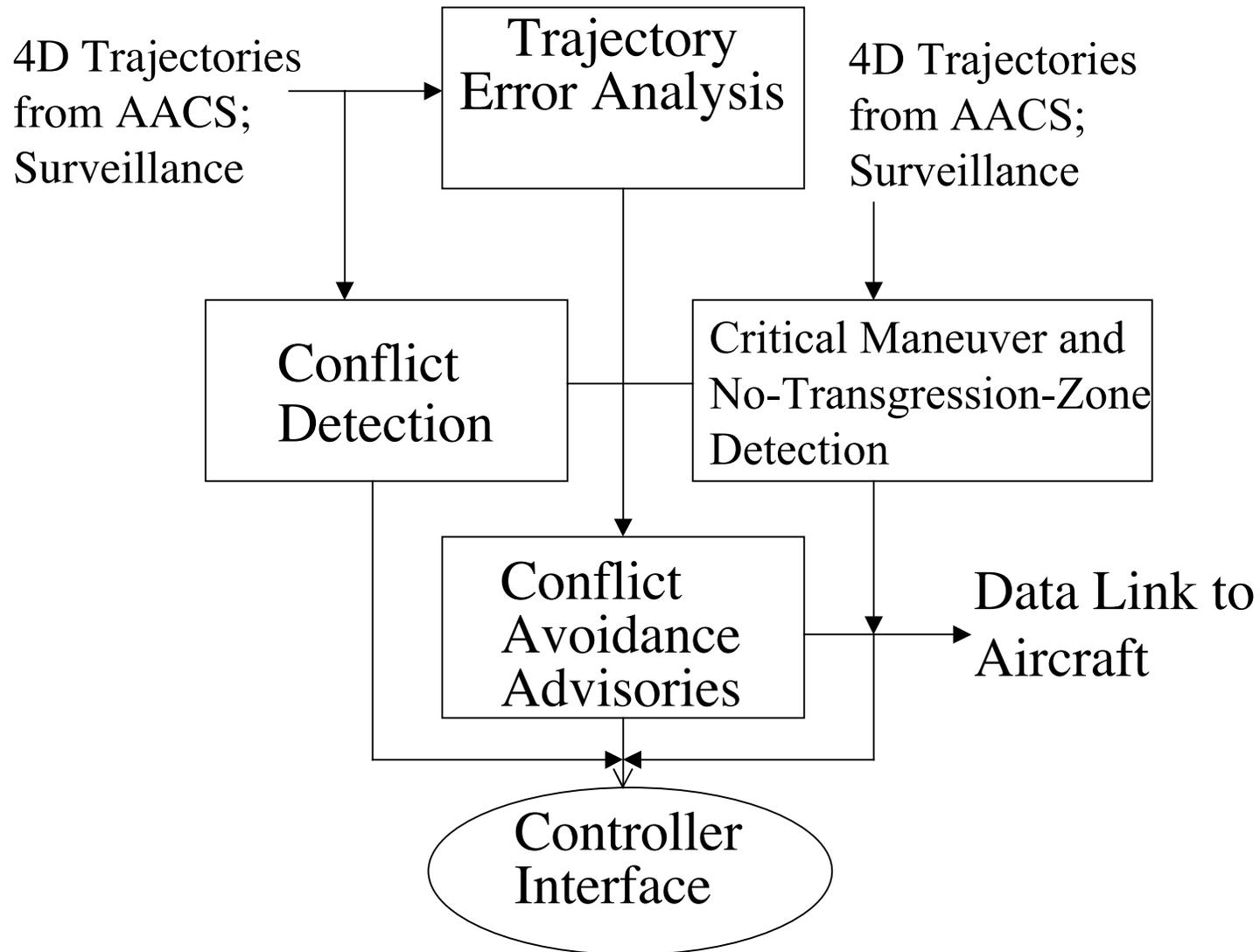
Advanced Airspace Architecture



Why TSAFE is needed

- AACS is designed to solve a defined set of problems; however, its regions of solvable and unsolvable problems are indeterminate.
- Complexity of AACS software makes it difficult to establish its capabilities in providing tactical separation assurance.
- A separate system, TSAFE, whose main purpose is to provide tactical separation assurance, is less complex to design and easier to validate
- TSAFE uses knowledge of intent to warn against loss of separation
- The airborne collision avoidance system, TCAS, protects against collisions without knowledge of intent

TSAFE Architecture

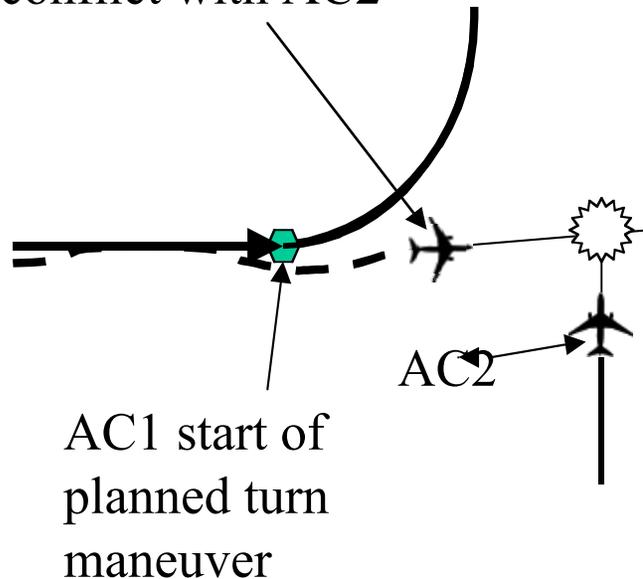


TSAFE Conflict Detection and Avoidance Strategy

- Short detection horizon (~ 3 min.)
 - 3D velocity vector combined with near term flight plan intent is used for trajectory prediction
- Critical maneuver and no-transgression-zone alerts
- Conflict alerts with ~ 2 min. warning time to loss of separation
- Avoidance maneuvers to provide a short period of conflict-free flight (~ 3 min.)
 - Climb (or descend) to an assigned altitude level
 - Turn right (or left) to an assigned heading
 - AACS or controller follows up with strategic solution

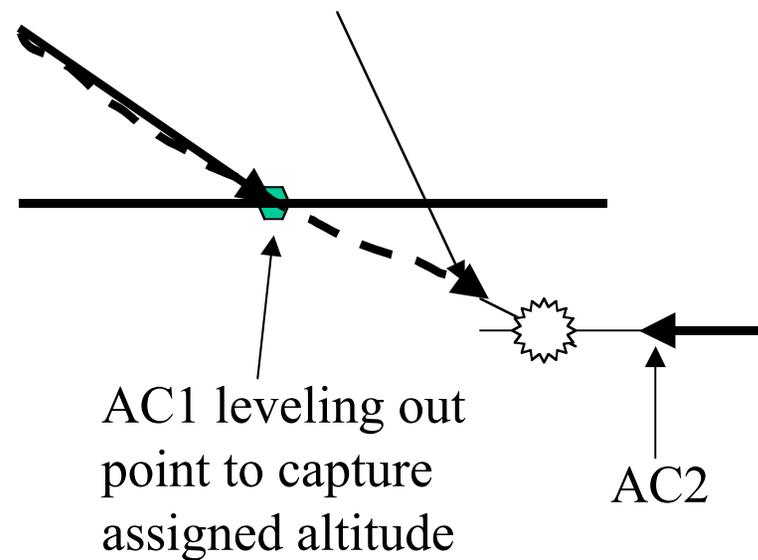
TSAFE Critical Maneuver Detection

Failure of AC1 to start planned turn on time produces immediate conflict with AC2



(a) Critical horizontal maneuver

AC1 descending below assigned altitude produces immediate conflict with AC2



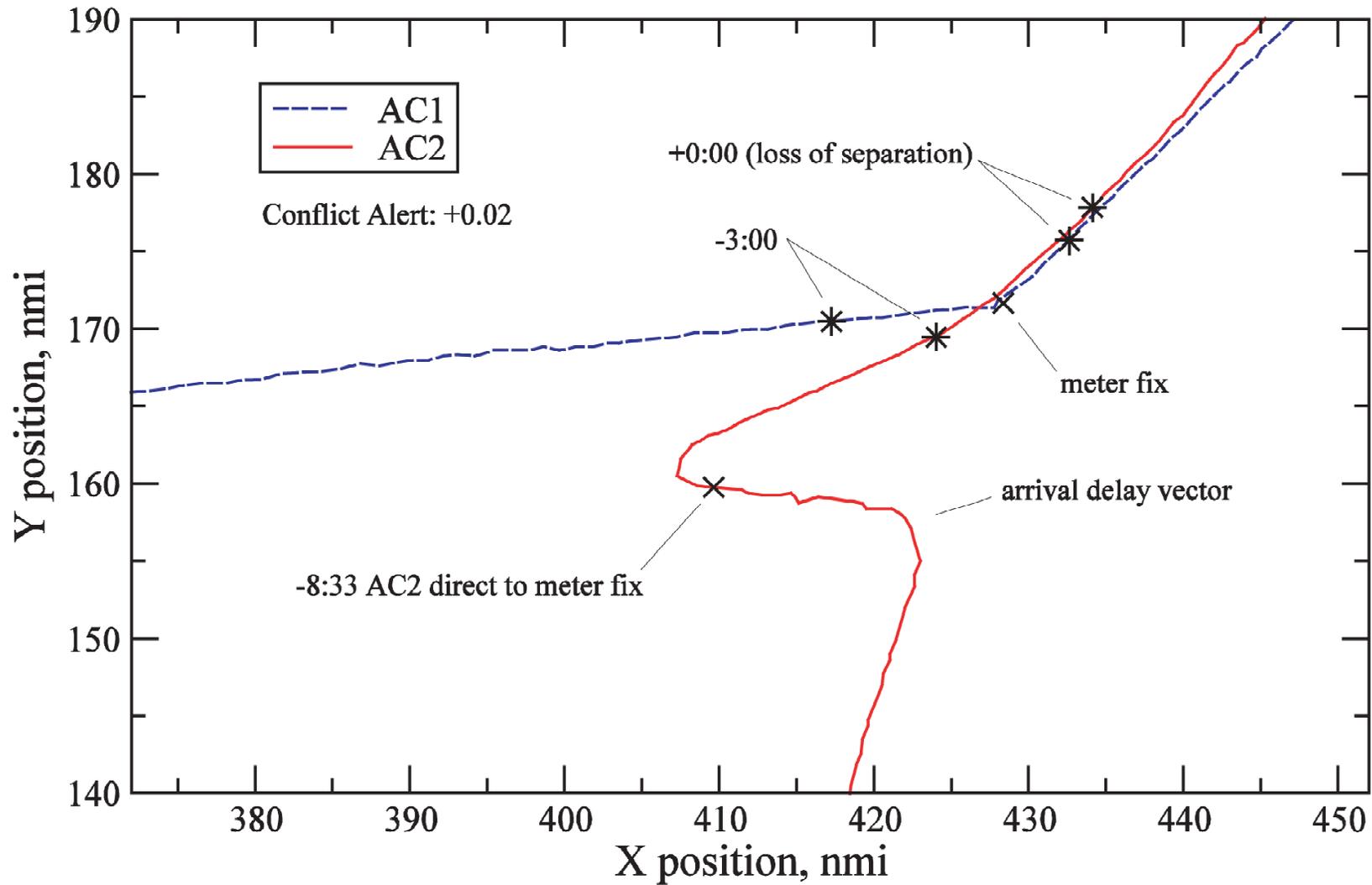
(b) Critical vertical maneuver

TSAFE Development Approach

- Develop performance requirements by collecting and categorizing operational error data from historical records (in progress):
 - Error / deviation reports
 - Radar tracking data
 - Most errors found to have occurred during climb or descent
- Incorporate TSAFE functions in CTAS for research and evaluation (in progress)
- Evaluate TSAFE's alerting techniques by using recorded and live tracking data (in progress) .
- Prepare for controller and pilot-in-the-loop simulations field evaluation

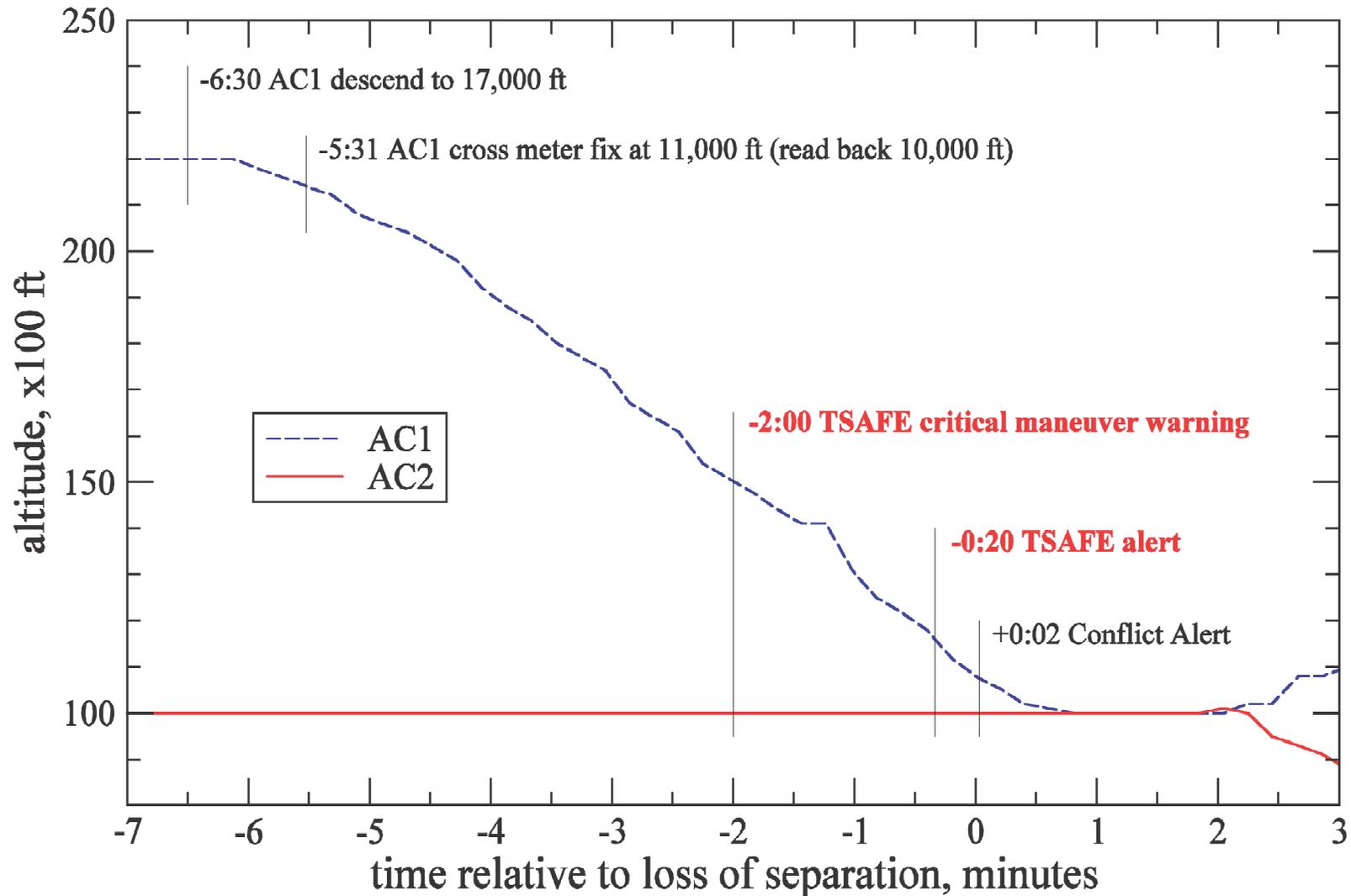
Example of TSAFE Critical Maneuver Alerting

(a) Ground Tracks

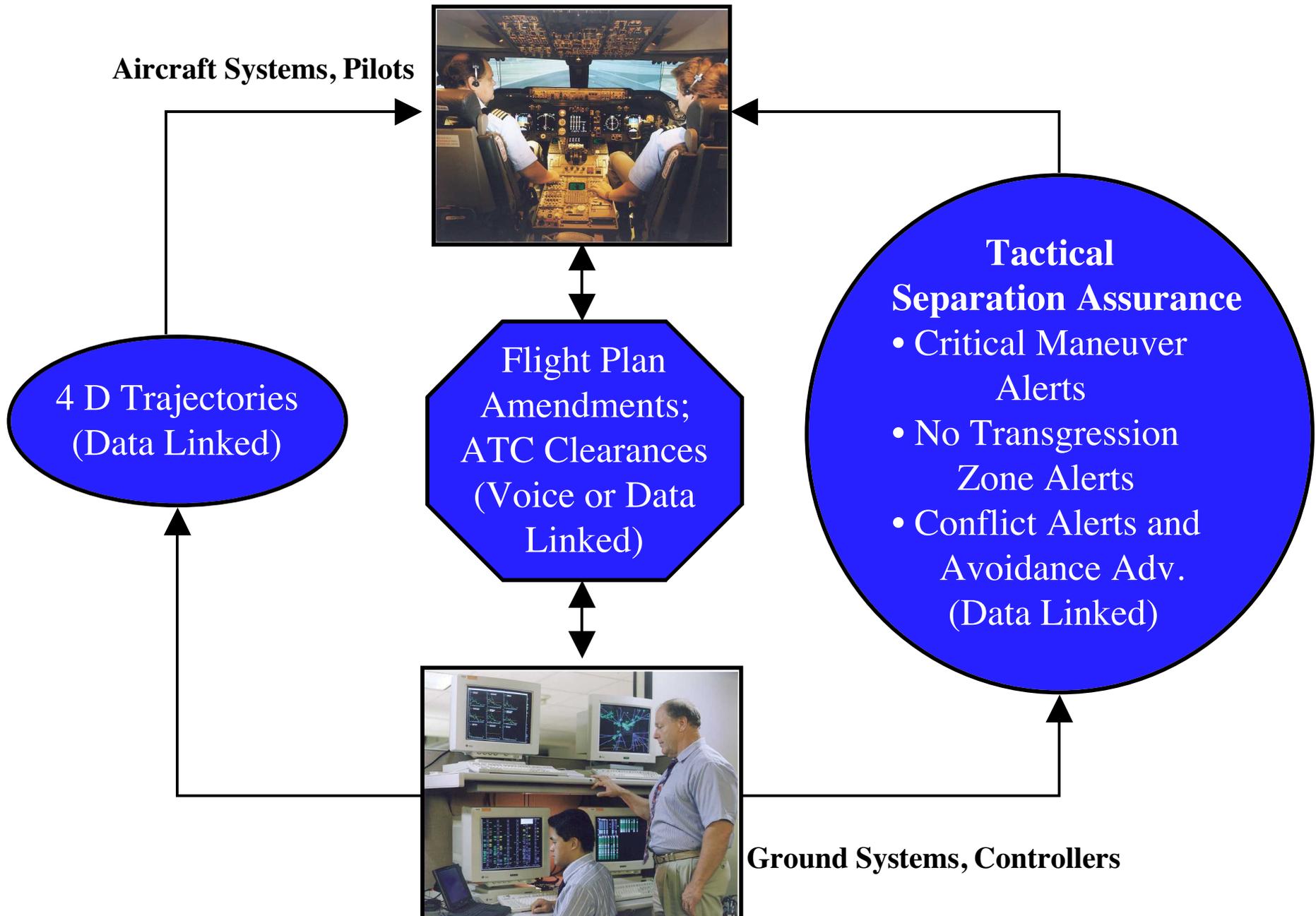


Example of TSAFE Critical Maneuver Alerting

(b) Altitude Profiles



Ground-Air Interactions in Advanced Airspace



Operational Responsibilities

Controller

- Traffic flow management
- Weather rerouting
- Special situation problem solving
- Handling and separation monitoring of unequipped aircraft
- Failure management

Equipped Aircraft Pilot

- Flight management, control and navigation
- Trajectory re-planning via ground system interface
- TSAFE critical maneuver monitoring and conflict resolution advisory execution
- TCAS alert response

Concluding Remarks

- Capacity of airspace is limited by controller workload associated with separation assurance
- Airspace has potential for more than twice the capacity of current system without changing current separation rules
- Advanced Airspace Concept has potential to increase capacity substantially by reducing controller workload associated with tactical separation monitoring and control
- Elements of Concept have been outlined:
 - Ground-based system provides 4D trajectories to equipped aircraft via data link
 - TSAFE provides separation assurance advisories to pilots via data link and protects against certain types of failures
 - Controller performs strategic control tasks and handles unequipped aircraft
- TSAFE has potential to reduce operational errors in current system