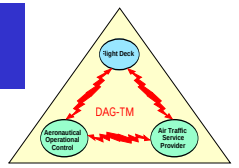
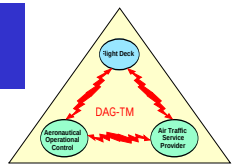


Concept Element 5

En Route: Free Maneuvering
for
(a) User-Preferred Separation Assurance
(b) User-Preferred Local TFM Conformance

David Wing
NASA Langley Research Center



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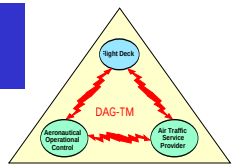


En Route (*&Transition*): Free Maneuvering

for User-preferred Separation and Local-TFM Conformance

Problem:

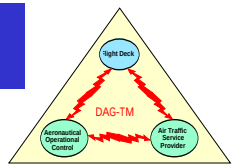
ATSP cannot accommodate trajectory change requests due to workload; and ATSP-issued clearances often cause excessive deviations for separation assurance or are otherwise not preferred by users

Solution:

- **Air: Equipped aircraft maneuver freely for separation & local-TFM conformance**
  - » **Trajectories account for the latest weather, SUA, and local TFM constraints for airport/airspace capacity (e.g., scheduled time-of-arrival (STA))**
- **Ground: ATSP establishes any necessary flow constraints (e.g., STA), and:**
  - » **Monitors the traffic situation and provides advisories as necessary**
  - » **Assures separation and local-TFM conformance for unequipped aircraft**

Potential Benefits:

- **Increased safety in separation assurance**
- **Increased user flexibility / efficiency (preferred trajectory)**
- **Increased user flexibility/efficiency in the presence of dynamic constraints**
- **Reduced ATSP workload**
- **Reduced excess separation buffers**
- **Reduced voice communications**

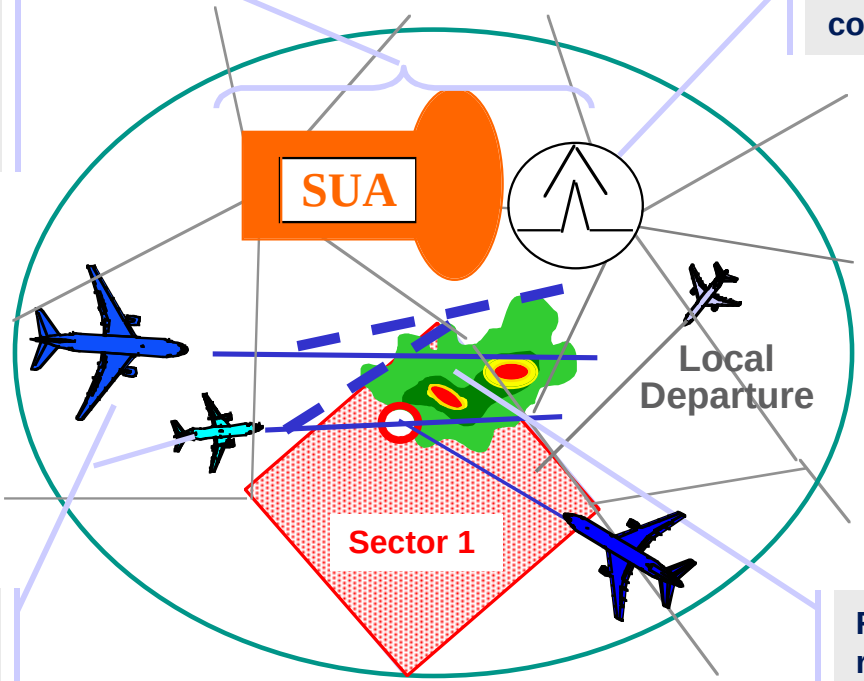


Summary of CE-5 Unique Features

- Responsibility for safe and efficient operation of the NAS is distributed between flight crews and ATSP
- Authority for autonomous operations, and responsibility for separation assurance, delegated to aircraft that voluntarily equip with flight deck intelligent decision aids (➞ "autonomous" aircraft)
  - Autonomous aircraft receive constraints from ground-based systems (e.g., required time of arrival at a fix, SUA avoidance) and are allowed to *self-optimize* their flight paths to meet those constraints
- ATSP provides separation and flow management for all other (IFR) aircraft (➞ "managed" aircraft) with the assistance of controller intelligent decision aids
- Autonomous and managed aircraft operations are integrated in airspace

Constrained Airspace Challenges

Plan across multiple sectors and multiple facilities,
- involving several human planners
- using best available information



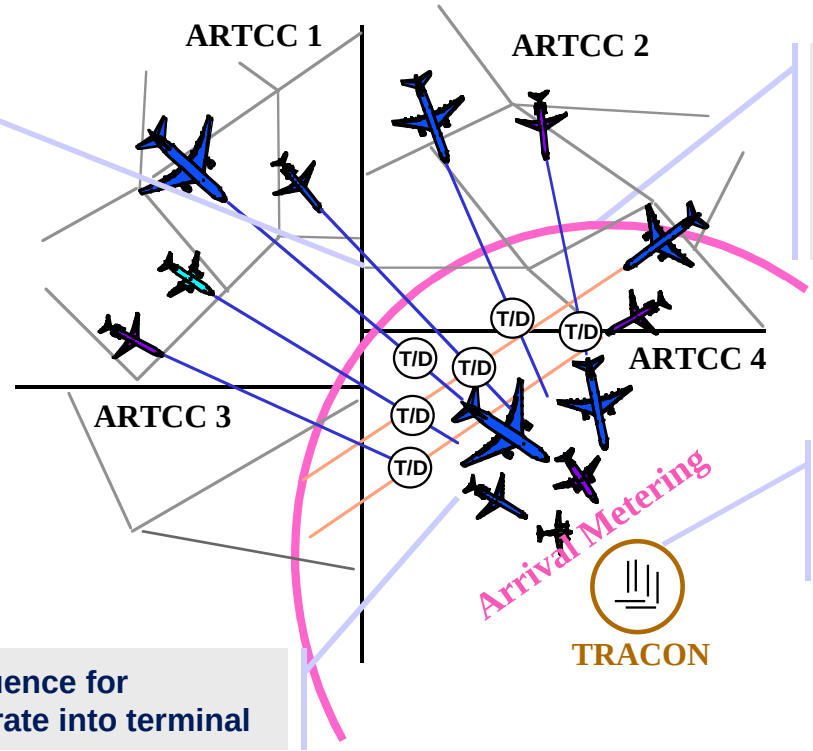
Maintain passenger comfort

Maintain separation with other aircraft, which may have significantly different performance and navigation capability

Reroute around weather & restricted airspace while avoiding bottlenecks

Transitional Airspace Challenges

Comply with inter-facility flow management constraints (en route spacing)

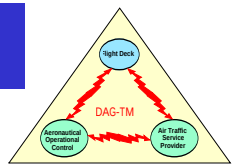


Plan and execute conflict-free user-preferred arrival trajectories.

Comply with terminal flow management constraints (miles-in-trail or metering)

Merge and sequence for maximum flow rate into terminal

T/D Top of Descent



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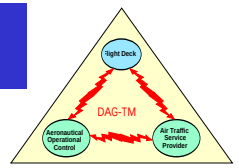


A Diverse Set of Research Issues for CE-5 Were Identified and Categorized

(page 1 of 2)

"Operations" Categories

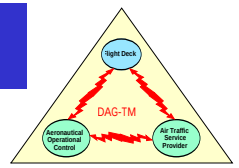
- Separation assurance while adhering to RTA
- Mixed-equipage integration and segregation
- Time horizons
- Intent transfer & inference
- Traffic situation complexity
- Flight rules
- Environmental predictions
- CNS infrastructure & aircraft capability limitations
- Global interoperability
- Equitability, access, stability

"Decision Support" Categories

- Overall functionality: FMS designed for autonomous operations
- Overall functionality: ATSP DST designed for trajectory-oriented ops
- Human-centered design
- Interface (display, input, alerting)
- Constraint management
- Intent information handling
- RTA-capable CD&R algorithms
- User preference handling
- Traffic situation complexity prediction (ATSP)
- Inter-sector coordination (ATSP)

"Data Exchange" Categories

- Content, frequency, accuracy
- Data link mechanism



A Diverse Set of Research Issues for CE-5 Were Identified and Categorized

(page 2 of 2)

"Human Factors" Categories

- Roles & responsibilities
- Managing distributed & shared responsibilities
- Workload mgmt, task balancing
- Using automation
- Working within time horizons
- Managing constraints
- Transferring responsibility
- Coordination and negotiation
- Error assessment and recovery

"Procedures" Categories

- Airborne autonomous ops
- Mixed-equipage ops
- Trajectory-oriented ATSP
- Intervention
- Transfer of responsibility
- Degraded-mode ops
- Situation awareness maintenance
- Constraint management
- Traffic situation complexity

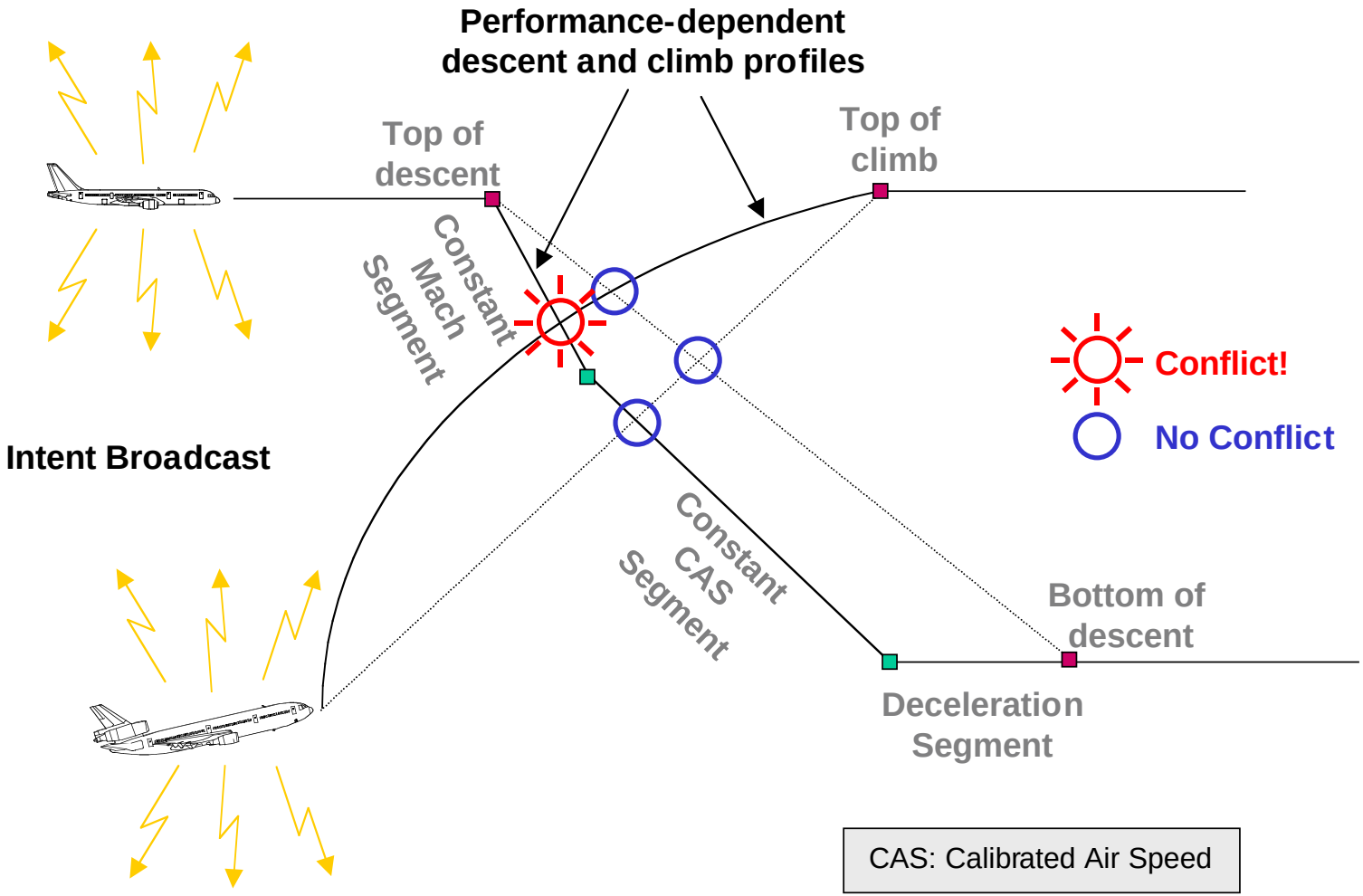
"Safety" Categories

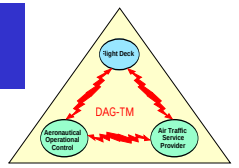
- CNS failures / redundancy
- Automation failures
- Decentralized authority
- Non-compliant participants

"System Performance" Categories

- Traffic situation complexity
- Weather system severity
- Decentralized decision making
- Stability in competition

Example: Trajectory Prediction Accuracy
How Much Intent Information is Needed?

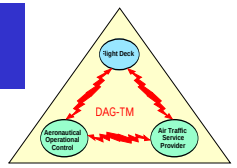




Feasibility Research

Premise: "Feasibility is questioned in the *significant* departures from current operations"

- Integrated operations of autonomous and managed aircraft
- Routine and explicit transfer of separation responsibility
- Local TFM distributed by planning / conformance
- Flight crew manages new flexibility and responsibility with current tasks
- ATSP performs services with non-structured routing
- ATSP performs services based on trajectory orientation
- Extended separation assurance planning to meet local TFM constraints
- Sharing of intent information to meet human-participant preferences
- Increased dependence on intelligent decision aids
- Increased dependence on CNS technologies



Competing Hypotheses of Feasibility
an example

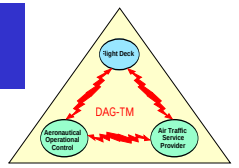
Integrated operations of autonomous and managed aircraft

Supporting hypotheses

- Autonomous aircraft can ensure separation w/o knowledge of ATSP intent or traffic aircraft performance
- ATSP can simultaneously control "managed" aircraft and monitor "autonomous" aircraft, while maintaining global situation awareness

Refuting hypotheses

- Perceived traffic complexity elevates ATSP perceived task load, inhibiting performance of routine services
- Missed-RTA resequencing difficult without centralized control



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Flight Systems for Autonomous Operations

Flight Management System with Extended Capability

Autonomous Operations Planner

- Conflict detection & resolution
- Intent inference
- Local traffic flow management

Integrated Cockpit Display

- Navigation
- Traffic Information
- Trajectory Planning

Onboard CNS Systems

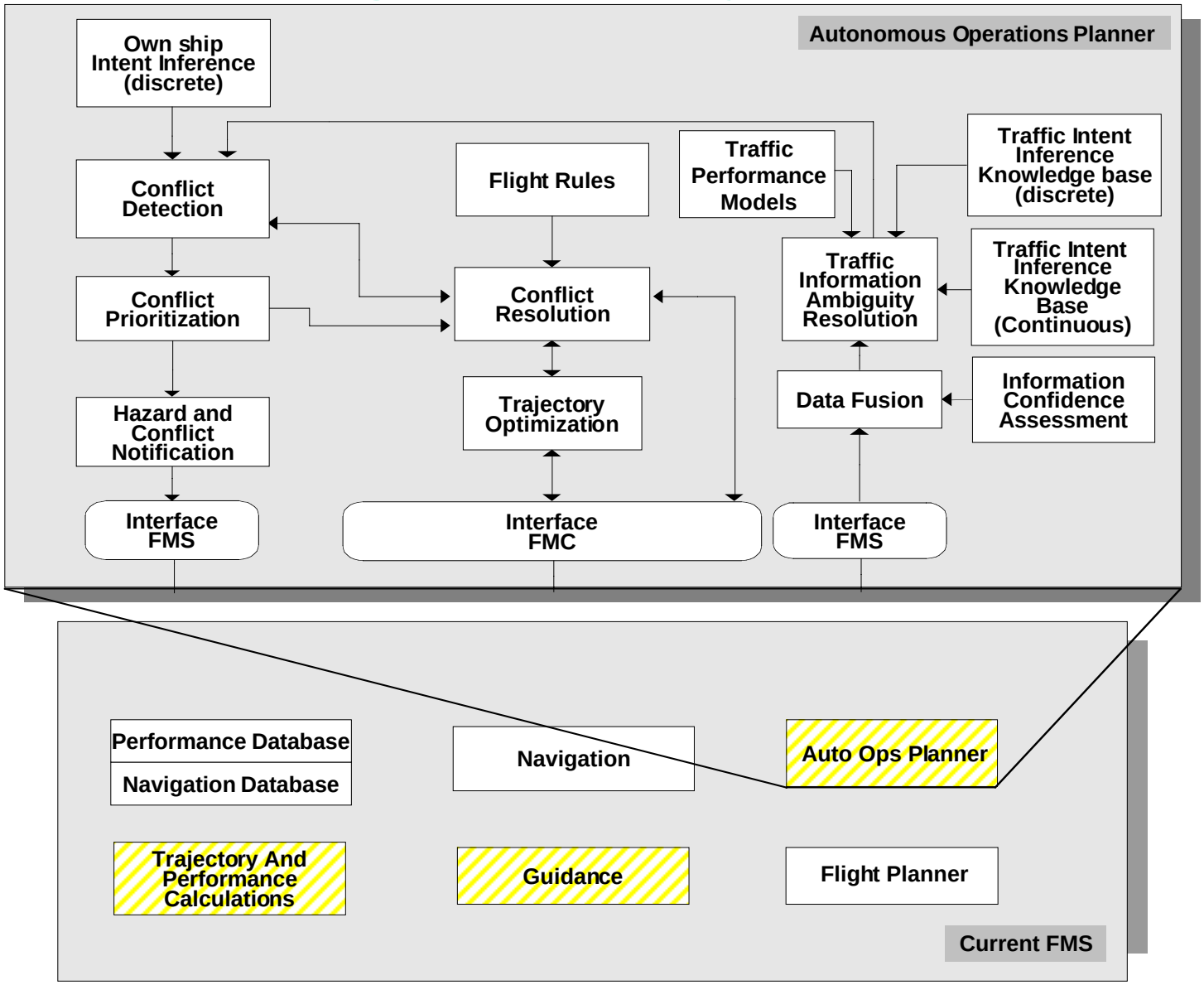
Digital Data Link Communications

Global Positioning System Navigation

Automatic Dependent Surveillance - Broadcast

Traffic Alerting & Collision Avoidance System

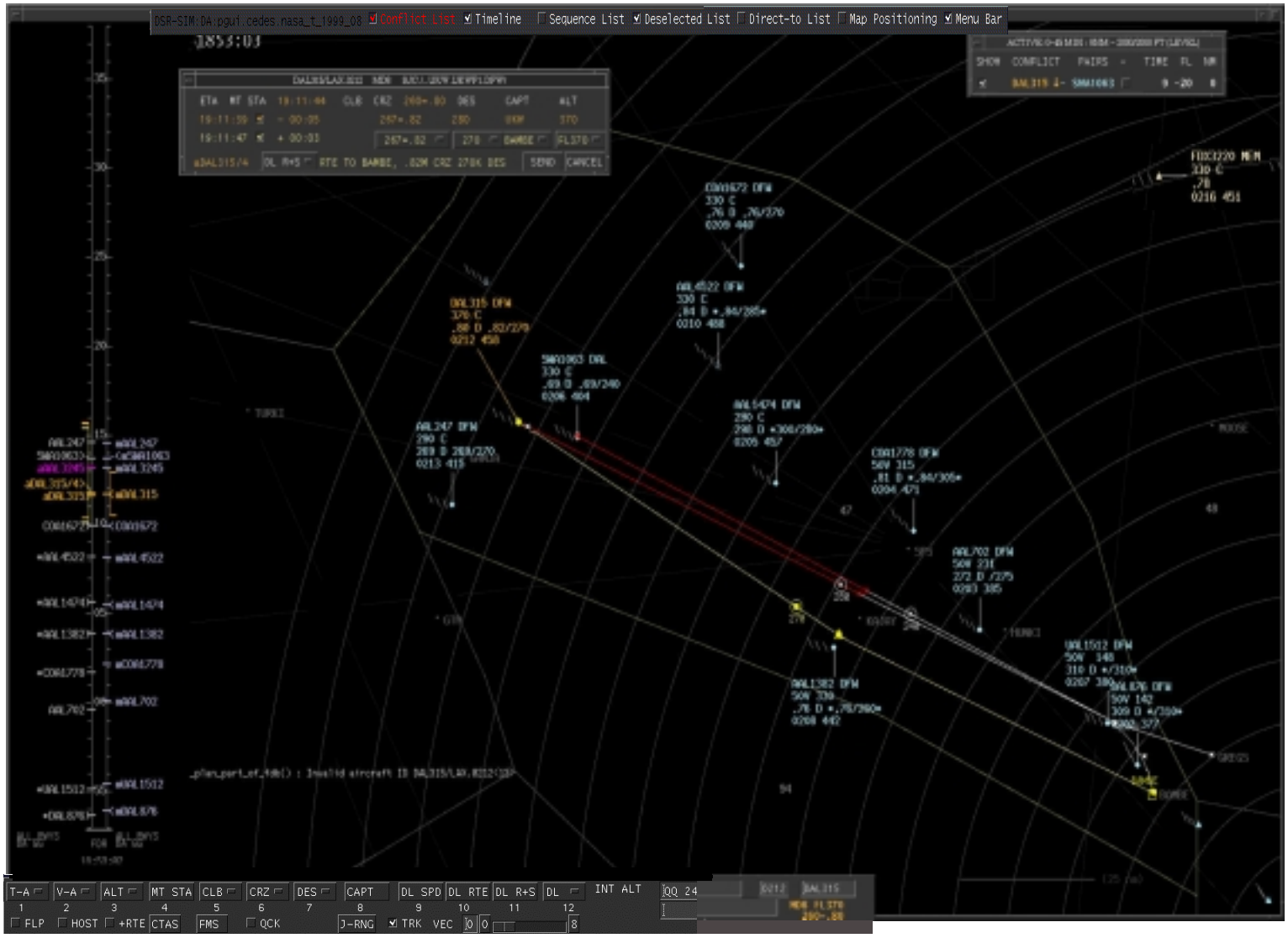
Extending the Capability of the FMS

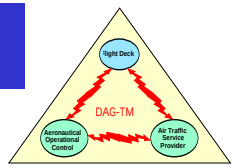


Integrated Cockpit Display

- **4D intent and traffic information**
  - 3D Flight Plans
  - Individual aircraft ID blocks
  - Static and dynamic predictors
  - Three levels of relative altitude color coding (co-altitude, above, and below)
- **Situational awareness information**
  - Multistage strategic conflict alerts
  - Traffic relevance coding (i.e. temporal proximity, "free flight" status) using intensity levels and symbol shape (nose)
- **Anti-clutter features:**
  - Full and partial data blocks (Tail tags)
  - Individually controllable data blocks
  - Smart Tags
  - Global ID and Route Declutter
- **Captain/First Officer display sharing**
- **Touchpad and panel-mounted controls**

ATSP Automation Tools





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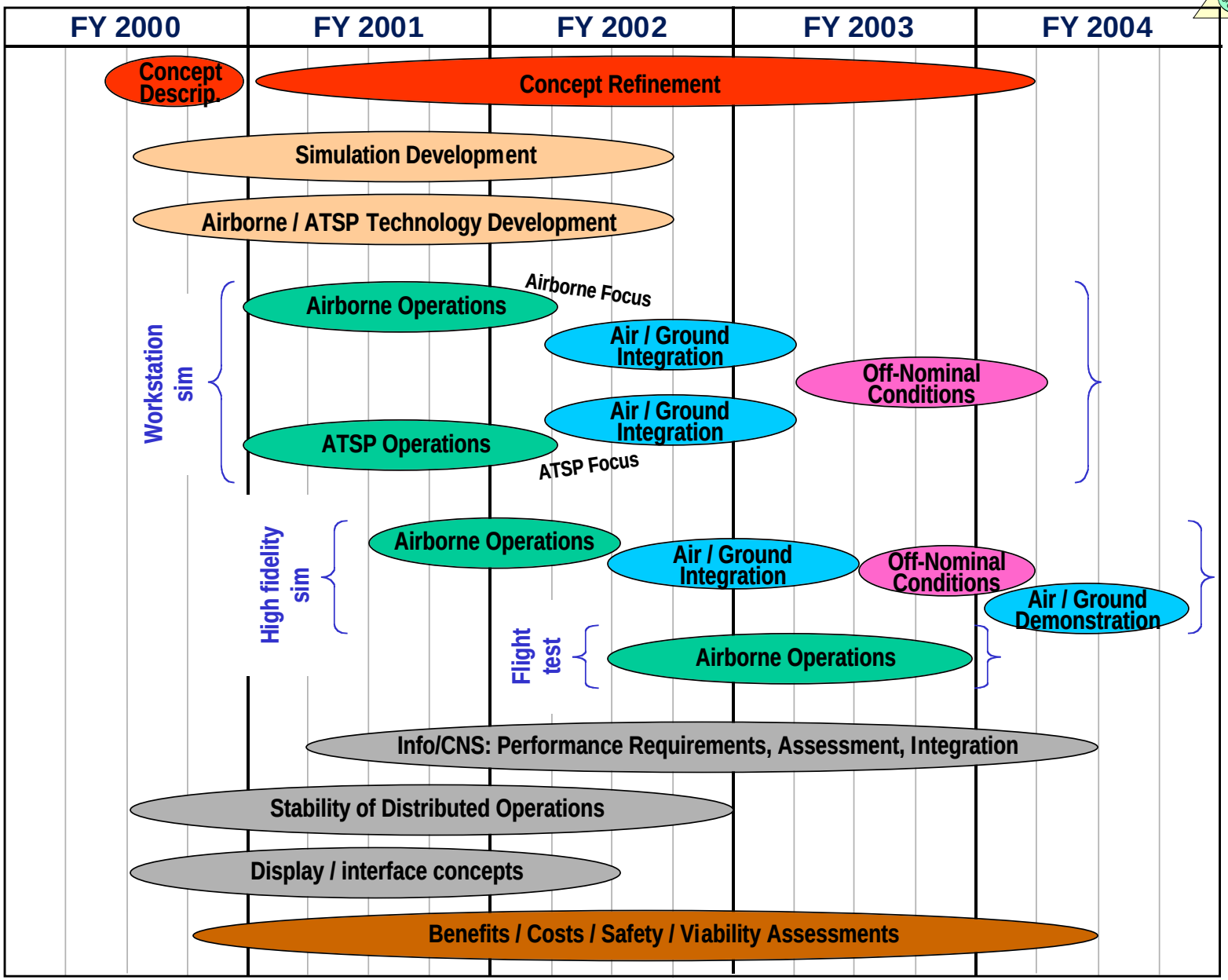
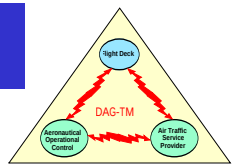
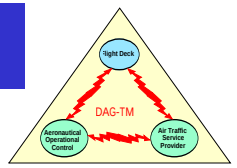
En Route Free Maneuvering





Methodologies and Research Strategies

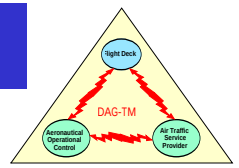
- Workstation-based simulations
  - Human in-the-loop investigations, development
  - Batch studies involving large numbers of aircraft; statistically significant data sets
- Flight Testing
  - Assessment of operational performance
  - Validation of simulation assumptions and conclusions
  - Demonstrate trajectory adherence, autonomous route planning and hazard avoidance
- High-fidelity Simulations
  - Procedure development for use with new airborne technologies
  - Greater control of environment than can be achieved in flight
  - Final verification of airborne technology prior to flight testing



Methodologies Development: NASA Free Flight Simulation

Objectives

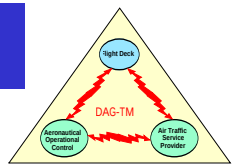
- Determine system-level operational feasibility of mature-state and mid-term free-flight concepts
- Identify system functional requirements
- Provide a platform for system design
- Generate performance data for benefits assessment
- Enable clear demonstration and explanation of free-flight concepts to others



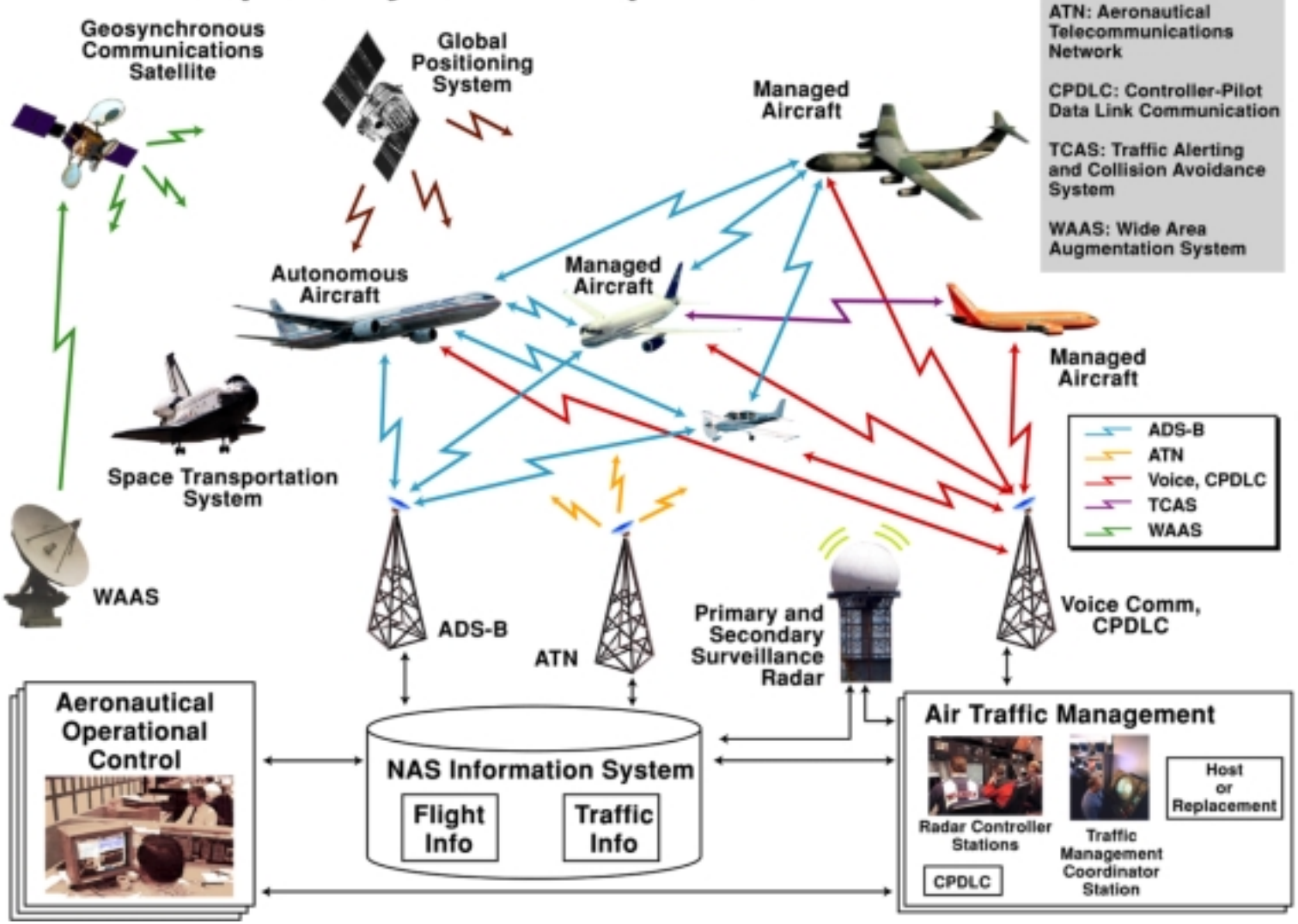
Free Flight Simulation Characteristics

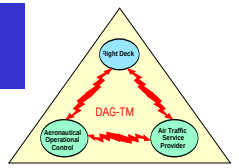
- Functionality
  - Representation of actual en route airspace, with at least three adjacent sectors (initially ZFW sectors 28, 89, 86)
  - Parametric representations of each major component of anticipated Communication, Navigation, and Surveillance infrastructure
  - Component-level functional models of airborne and ground-based system hardware and decision support systems
  - Performance-level representations of several aircraft types
  - Scenarios that represent realistic traffic and airspace environments
- Humans in the Loop
  - Subject-pilots, Subject-controllers, and Subject-dispatchers will use computer workstations that will allow them to make flight- or traffic-management decisions as they would in a deployed system
- Simulation of existing ATC system at equivalent level for comparison

En Route Free Maneuvering



NASA Free Flight Simulation
National Airspace System Components





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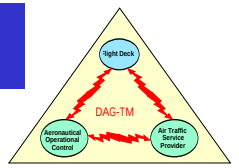

Presentations

- Jim Kuchar, MIT

  "Decision-Aiding and Alerting System Development for DAG-TM"

- Jacco Hoekstra, NLR

  "NLR Free Flight"

- Michael Agelii, SAS

  "Operational Application of DAG-TM in European NUP Project"