NEXT GENERATION SATELLITE SYSTEMS FOR AERONAUTICAL COMMUNICATIONS

Participating Units at U of Maryland:

NEXTOR: National Center of Excellence for Aviation Operations Research

CSHCN: Center for Satellite and Hybrid Communications Networks

Michael Ball
Leandros Tassiulas
Özgür Erçetin

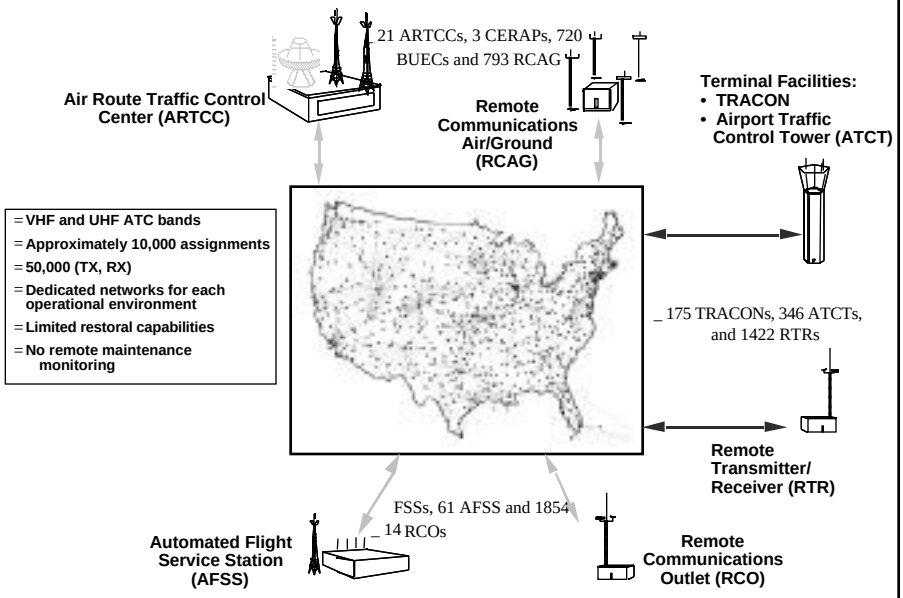
Types of Communication Services

- **Safety Communications**
  - Air Traffic Services (ATS)
    - Air Traffic Control.
    - Weather and Flight Information Services.
  - Aeronautical Operational Control (AOC)
    - Dispatch, Flight Planning, and independent company communications.

Types of Communication Services

- **Non Safety Communications**
  - Aeronautical Administrative Communications (AAC)
    - Cabin Provisioning, other company related non-safety communications.
  - Aeronautical Public Correspondence (APC)
    - Public Correspondence, personal communications by/for passengers.

Air/Ground Communications



Current VHF ATC Communication System

- **The communication between controllers and pilots is analog and voice-only, and achieved via terrestrial remote radio stations positioned across the country.**
- **VHF system consists of 47,000 ground-based radios at 3,700 locations. 800 of these sites are for en-route communications.**
- **ATC communication is performed over the frequency bands VHF 118-136MHz (civilian), and UHF 225-400MHz (military).**

Current VHF ATC Communication System

- **FAA estimates that about 54 million flights will have to be handled annually by 2002.**
- **Current VHF system is old and the capacity is inadequate for the current increase in air traffic.**
- **Some disadvantages of the current VHF system are:**
  - Low utilization, voice congestion,
  - Inefficient, e.g. 1 in 7 messages is a handoff.
  - High failure rates for the aging equipment, susceptibility to channel blockage.
  - Interference and lack of security.

Current Data Link ACARS

- **Currently, data link is used by AOCs for non-safety air/ground communications.**
- **ARINC provides VHF ACARS service to over 6000 aircraft, using the 4MHz of AMS spectrum.**
- **ARINC also provides HFDL and SATCOM service for oceanic ATC.**

Planned Data Link Evolution

- **ARINC will be contracted to provide data link with VDL2 standard for Controller to Pilot Data Link Communications (CPDLC) starting in 1999.**
- **By 2002, FAA plans to use digital NEXCOM radios for both voice and data.**
- **Aeronautical Telecommunications Network (ATN)**
  - VHF A/G resources will be interconnected for efficient use of the resources and to support new capabilities such as intrinsic backup.

VHF TDMA System En-Route Data Link Services

- **Initial Contact, Altimeter setting**
- **SIGMETs, PIREPs**
- **Weather Advisories**
- **Route Amendments, Traffic Advisories**
- **Speed Adjustments/Restrictions**
- **Frequency Changes/Routine Handoffs/Transfer of Radio Communications**
- **Traffic Management Information**
- **Flight Plan Amendments/Routings**

Next Generation Satellite Systems

- **Future medium for aeronautical communications.**
- **Broad feasibility study by RTCA has shown that the proposed LEO/MEO systems are feasible.**
- **Key considerations for the feasibility study are:**
  - Compliance with AMSS SARPs.
  - Spectrum availability and interference protection.
  - Technical considerations of coverage and capacity.
  - Service interoperability
  - Economic viability.

Advantages of Next Generation Satellite Systems

- **Global coverage including polar regions.**
- **Increased communication capacity.**
- **Higher frequency re use.**
- **The potential for universal equipage.**
- **Free flight.**
- **Economic benefits.**
  - Cheaper, smaller equipment, thus smaller non-recurring and recurring costs for the airlines.

Fundamental Assumptions of Proposed Research

- **Although biggest frequency congestion is at the terminal areas, the economic viability will be driven by en route communications.**
- **Terminal area communications capacity will be enhanced by off-loading some en-route spectrum to SATCOM.**
- **Hybrid ground-based/SATCOM architecture.**
- **Concentrate on systems issues.**

Perspective of Various Players

- **FAA:**
  - reduction in cost of ground-based infrastructure
  - ability to handle increasing demand
  - new services/features
- **Airline motivator: bottom line $$ -- benefits must justify the costs**
  - revenues/benefits from “back of plane” services
  - new capabilities: oceanic/polar coverage, broadband data, ???
- **Satellite service providers:**
  - revenue potential must justify costs (usually implies bundling with passenger services)
  - aeronautical services not highest priority

Use of NGSS for Aeronautical Communications

Transition from VHF ground communication system to satellite systems will not be instantaneous

Near-term: oceanic/remote communications; satcomm virtual private lines connecting ARTCCs with BUECs and RCAGs.

Medium-term: hybrid architecture -- provides alternate data communications link for equipped aircraft; limited use for voice over continental US.

Long-term: hybrid architecture with reduced ground infrastructure -- voice and data; supports free-flight; equipped aircraft have added flexibility.

Use of NGSS for Aeronautical Communications

- **Equipage stages:**
  - Phase I: Aircraft flying over oceanic routes will be first to obtain NGSS equipment.
  - Phase II: The number of aircraft with NGSS equipment is significant so that use over continental US has impact on demand on ground-based facilities.
  - Phase III: Substantial percentage of the aircraft have NGSS equipment.

Use of NGSS as Virtual Private Lines Near term

- **Most of the remote radio sites (RCAGs and BUECs) are connected to ARTCCs via leased lines.**
  - BUECs intended for use only during RCAG failures.
  - The percent of the time BUECs and the connecting leased lines are used is quite small ==> extremely low link utilization.
  - Can NGSS provide virtual private line service to replace current leased lines?
    - A call is set up between corresponding ARTCC and the BUEC when the need arises.

Use of NGSS as Virtual Private Lines: Research Issues

- **Economic: What are the costs and benefits of such a system?**
- **Technical: Can NGSS provide acceptable call setup delay, call prioritization and channel availability.**

Use of NGSS as an Additional Level of Data Comm. (Medium term - Phase II)

- **Partition of users**
  - Provide SATCOM service to a limited number of users, i.e. users with the necessary equipment.
  - Aircraft with international and/or remote routes will be first to purchase the NGSS SATCOM equipment.
  - These aircraft, while on the domestic routes, may use the NGSS SATCOM for ATS, thereby offloading ground-based system.

Partitioning the Users: Research Questions

- **What SATCOM bandwidth requirements and system features are necessary**
  - to provide an effective data link
  - to insure that SATCOM can produce a significant reduction in demand on ground-based system.
- **For different penetration levels of SATCOM equipment, how much terminal area capacity is freed?**
- **What are the technical and operational requirements of such a system?**
  - e.g. handoffs (discussed later)

Use of SATCOM as an Additional Level of Communication (continued)

- **Partition the information -- transfer particular information types with different communication links, i.e. SATCOM, VHF data link, VHF digital voice.**
  - New data link applications, e.g. weather maps, weather advisories, are broadcast to many users and require high data rates.
  - SATCOM is a natural choice for non-time critical, high data rate information -- offloads spectrum for time critical data such as hand-offs and emergency voice.
  - Spectrum freed up for use in congested terminal areas, where voice will continue to be the primary means of communication.
  - For SATCOM, LEO/MEO has advantage over GEO: lower cost per call, smaller on-board equipment, lower round trip delays.

Partitioning the Information: Research Question

- **What are the appropriate data partitions between SATCOM and VHF data link?**
  - Consider the performance requirements and capacities of each medium and differentiate applications.

Control Responsibility between ATN Layer and NGSS Physical Subnet

- **There will be multiple physical links and physical subnets connected to ATN layer**
- **In theory ATN layer should find most efficient route to aircraft**
- **What is division of responsibility between ATN layer and NGSS subnet?**

ATC Voice Communication Based on Point-to-Point Connections

- **Limited use -- primarily for over-land portion of trans-oceanic flights.**
- **Point-to-point connection set up to ARTCC.**
- **How can these connections be integrated into existing system:**
  - setup delay
  - operational issues -- emulation of multi-cast connections
  - due to high setup delay, special handoff process may be needed

Multicast Call Problem in NGSS Long Term - Phase III

- **Requirement for provision of voice services equivalent to current operations:**
  - Party line capability required: all airborne users in a particular sector should receive all information broadcast by the controller of that sector.
  - These airborne users form a ***multicast group.***
  - Each sector may be serviced by multiple spot beams, which are moving as well.
  - As the aircraft flies on it's path, it changes spot beams as well as sectors.
  - The multicast group of a user has to be changed when it moves into a new sector.
- **What are the consequences and requirements of such a system?**
  - The handoff 's should be transparent to the controllers and pilots.

Transparent Handoffs

- **Transparent handoffs should be possible both for NGSS and NEXCOM, eliminating current voice communication overhead**
- **Sector-to-sector handoffs within an ARTCC**
  - on-site processing may be sufficient
- **Handoffs between two ARTCCs**
  - many cases: voice vs data, multi-cast vs unicast
  - problem may be similar to mobile wireless network handoff questions

Long term - Phase III: Terrestrial Comm Support Proved only along Air Route Highways

Shaded areas are air routes with guaranteed terrestrial communications
The remaining areas are serviced by SATCOM
Motivation: huge savings in ground infrastructure

Air Route Highways: Concepts

- Guaranteed terrestrial communication on the highways.
- Aircraft without SATCOM may use these highways to get from one major airport to another.
- Aircraft equipped with SATCOM, may have free-flight.

Air Route Highways: Research Questions

- What is the best *highway structure*?
- What are cost savings?
- What is impact on airspace congestion?
- What equipage policies will airlines adopt in response to such an architecture?

Long Term

- **Emerging applications will lead to much higher data link capacity requirements:**
  - Is NGSS the most effective and cost efficient way of providing this increased capacity?
- **Improvements in air traffic control by the use of NGSS.**
  - Broadcast delivery of the common information
  - Better voice/data integration
- **New approaches to sectorization.**
- **Free flight -- distributed control architectures -- fundamental changes in communications requirements**