ADS-B Performance in the TRACON for DAG-TM Concept Element 11

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Presentation Outline

- Description of ADS-B
- Description of DAG-TM Concept
- OPNET Modeling Environment
- Simulation Parameters
- Simulation Results
- Discussion

ADS-B Background

- Automatic Dependent Surveillance - Broadcast
- Defined in RTCA DO-242A
- Position, velocity, and status information broadcast from aircraft at regular intervals using information obtained from Global Positioning System (GPS) Satellites and onboard systems
- July 2002 Data Link Decision by FAA
  - High performance and commercial aircraft will use Mode S
  - General aviation will equip with Universal Access Transceiver (UAT)
  - Equipage is optional but equipped aircraft will have the increased situational awareness necessary for Free Flight.

DAG-TM Concept

- Distributed Air/Ground Traffic Management (DAG-TM) is part of the Advanced Air Transportation Technologies (AATT) Project in the NASA Airspace Systems Program.
- Flight crews, air traffic personnel, and airline operational centers will use distributed decision-making to enable user preferences and increase system capacity.
- For the purpose of NASA research into feasibility, DAG-TM has been divided into fifteen concept elements
  - CE-5, CE-6, and CE-11 are currently funded under AATT
  - This presentation focuses on the use of ADS-B in Concept Element 11.

DAG-TM Concept Element 11

- Concept Element 11 is Terminal Arrival:
  - Self-spacing for Merging and In-Trail Separation

- “Appropriately equipped aircraft are given clearance to merge with another arrival stream, and/or maintain in-trail separation relative to a leading aircraft.”

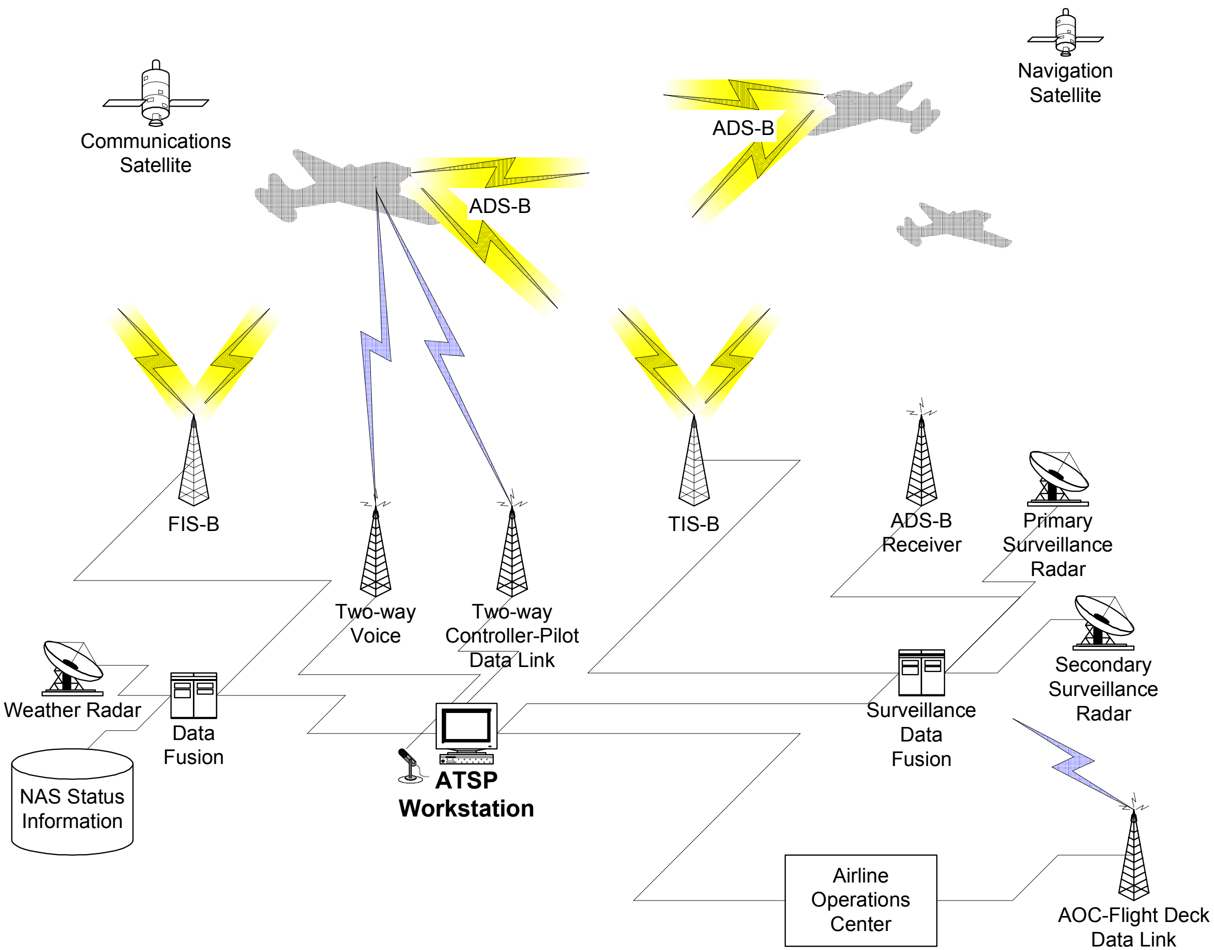
ADS-B Mode S Datalink

- Concept Element 11 of DAG-TM is envisioned to exist in the TRACON.
- Aircraft operating in the DAG-TM Concept of Free Flight will primarily be commercial and high performance GA aircraft
- Mode S technology was developed at MIT Lincoln Labs for use in Secondary Surveillance Radar.
- ADS-B makes use of the data link capabilities in Mode S
- Mode S Documentation
  - RTCA DO-181C
  - RTCA DO-260A (1090 MHz (Mode S) ADS-B and TIS-B)

UAT Data Link

- Although the FAA has chosen Mode S as the ADS-B data link for high performance aircraft, such as those that would benefit from the DAG-TM Concept, UAT is studied as an alternate due to limitations in the Mode S data link.
- The UAT data link for ADS-B, developed by MITRE is described in RTCA DO-282.

DAG-TM Surveillance Environment



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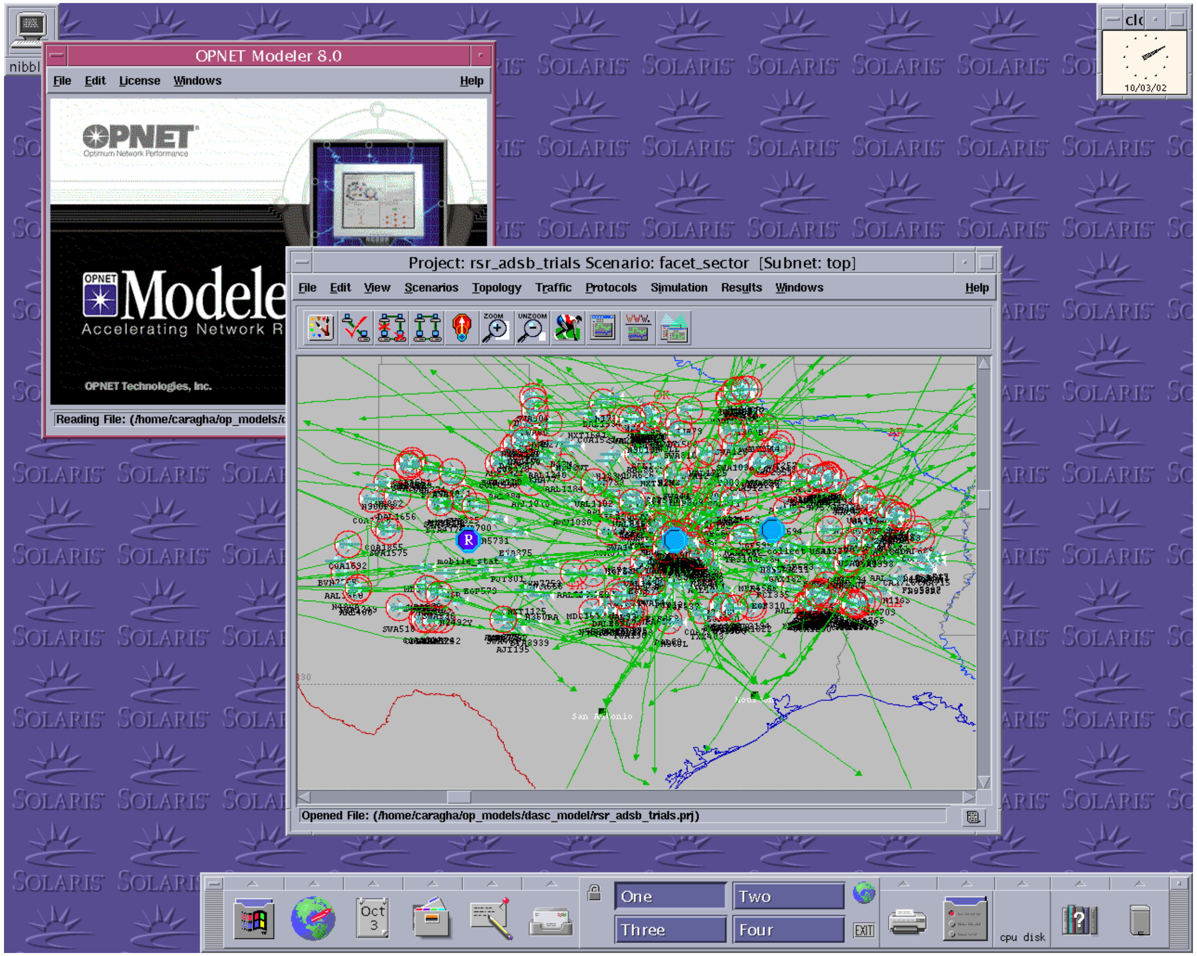
OPNET Modeling Environment

Glenn Research Center



OPNET Simulation Parameters – LA Basin 2020 scenarios

- LA Basin 2020 traffic file provided to NASA Glenn by researchers at Johns Hopkins Applied Physics Laboratory; file conforms to ADS-B traffic scenario in RTCA DO-242A
- SSRs assumed to be dual-mode Mode S / Monopulse ATCRBS
- Different classes of aircraft have different transmitter power. There is also a class for ground vehicles. ADS-B message distribution corresponds to RTCA DO-260A (draft).
  - In scenario with ATCRBS, Class A3 and A2 aircraft transmitted 1090 MHz ES ADS-B and replied to Mode S interrogations. Class A1 and A0 replied to ATCRBS interrogations.
  - In the other Mode S scenario, 100% of aircraft were Mode S equipped and transmitted ADS-B. No ATCRBS replies. Hence no TIS-B traffic.

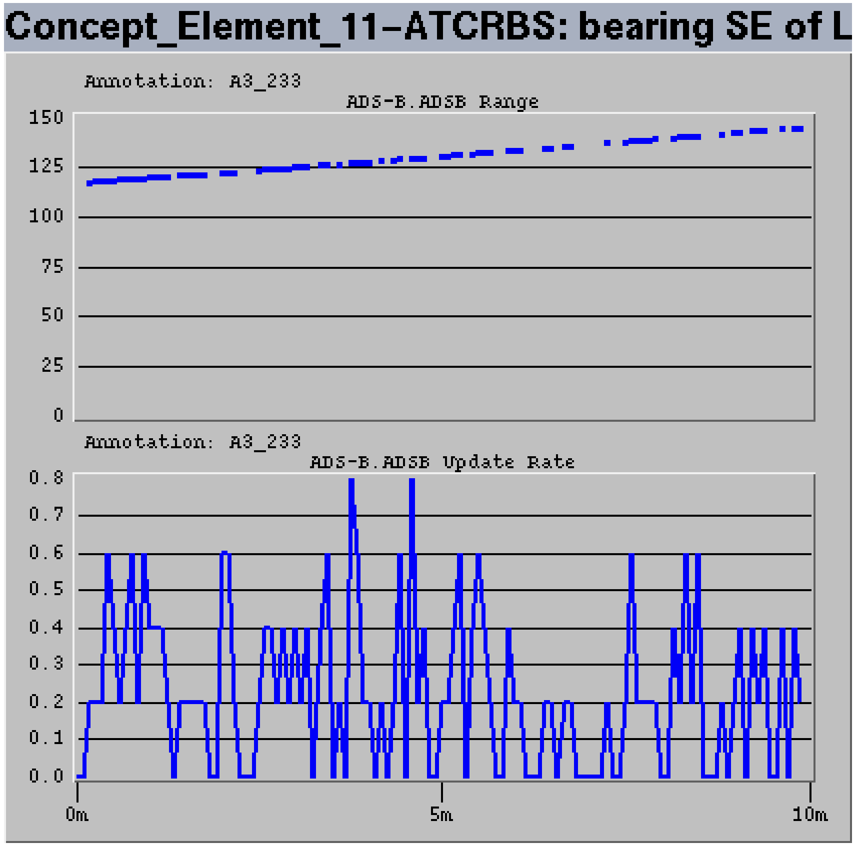
OPNET Simulation Parameters – LA Basin 2020 scenarios (cont.)

- Receiver aircraft collecting statistics had Class A3 MTL for transponder. One stationary at center of LA Basin at altitude of 5,000 feet. Four others, offset 50 miles north / south and east / west from center at 10,000 feet, descending 1,000 feet / minute.
- Reply rates to ground-based Mode S and ATCRBS radars determined based on numbers cited in 2000 FAA LA Basin report.
- ADS-B transmissions, Mode S replies, ATCRBS replies, and TCAS signaling were all on 1090 MHz.
- ADS-B messages on 1090 MHz ES above Class A3 MTL were successfully received unless interfered with by MORE THAN one other packet within +/- 6 dB during reception.

OPNET Simulation Parameters – LA Basin 2020 UAT Scenario

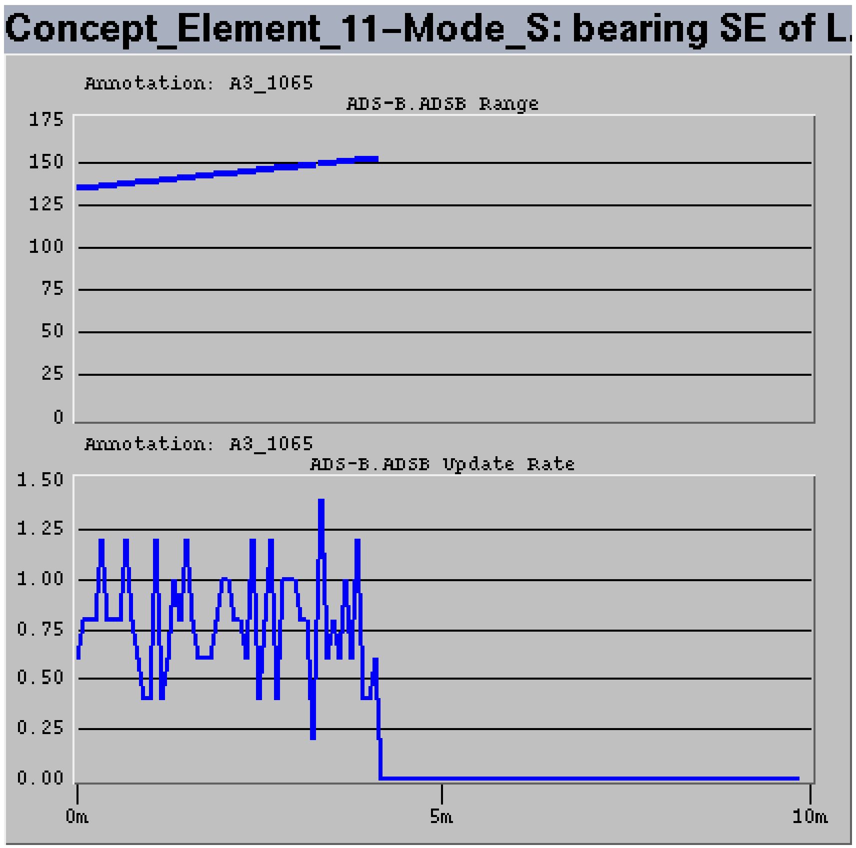
- Same distribution of transmitting nodes was used in UAT scenario as in Mode S scenarios.
- Receiver nodes were also Class A3 and similarly located
- Interference from DoD JTIDS communication system was NOT modeled
- UAT messages are transmitted once per second at varying times within the one second frame. The type of message transmitted varies based on the aircraft class over a 16 second interval
- Error rate of received packets is calculated from SNR based on CPFSK modulation curve

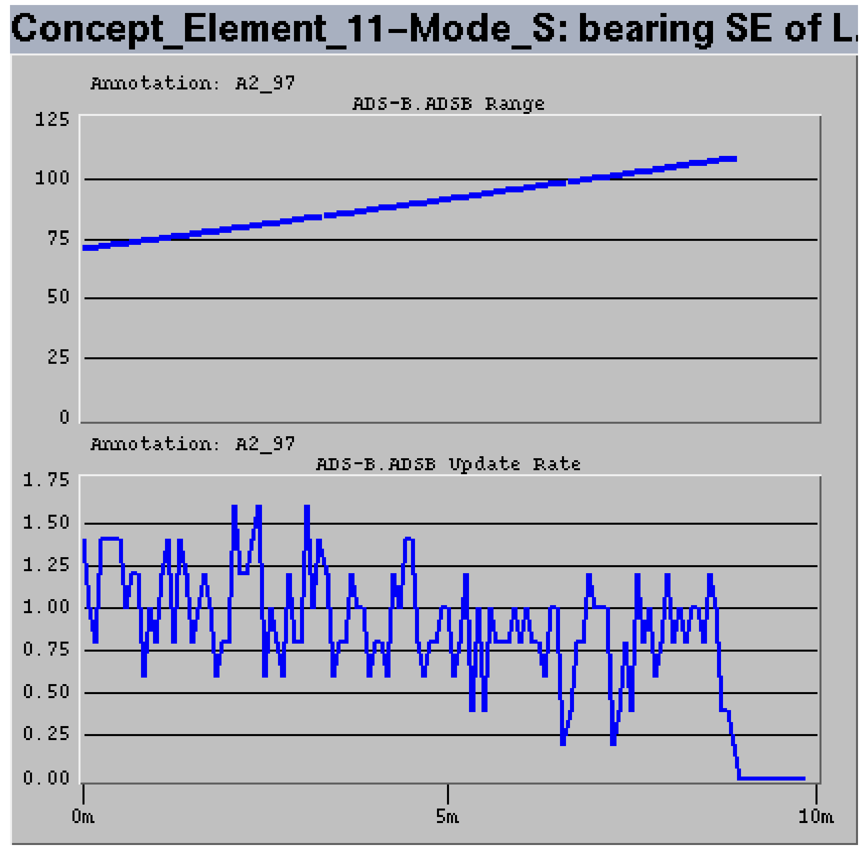
LA Basin 2020 Update Rate ATCRBS Scenario



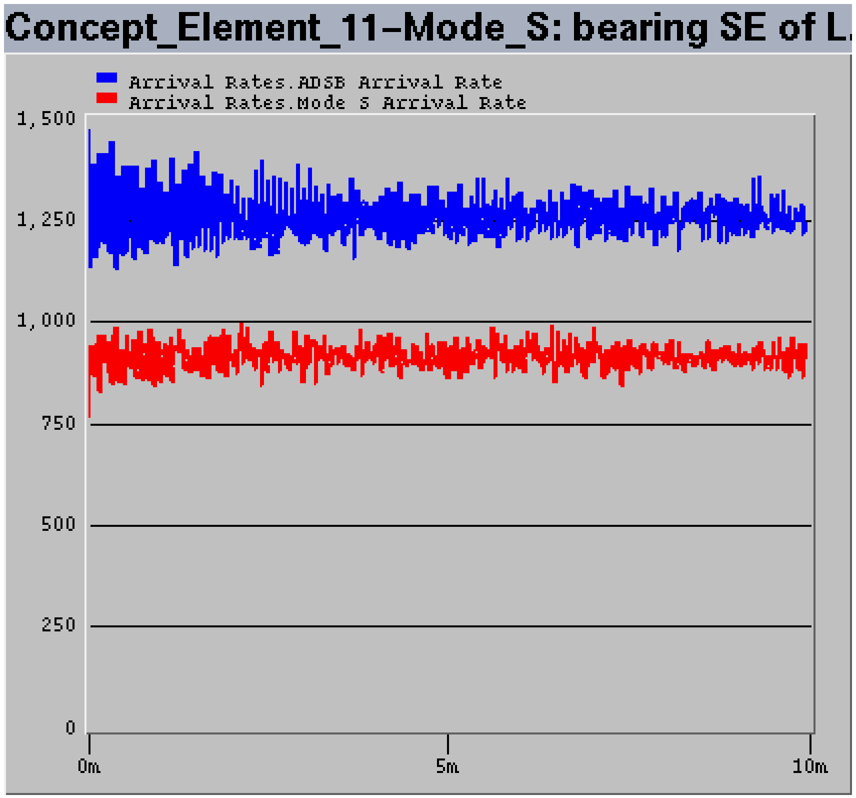
- Messages are received at ranges beyond 125 miles
- However only an average of 0.4 messages are received per second
- Full reception would be 2 messages per second
- Only 20% of messages are received
- Performance of 1090 ES ADS-B with ATCRBS interference is unacceptable

LA Basin 2020 Update Rate
100% Mode S Environment



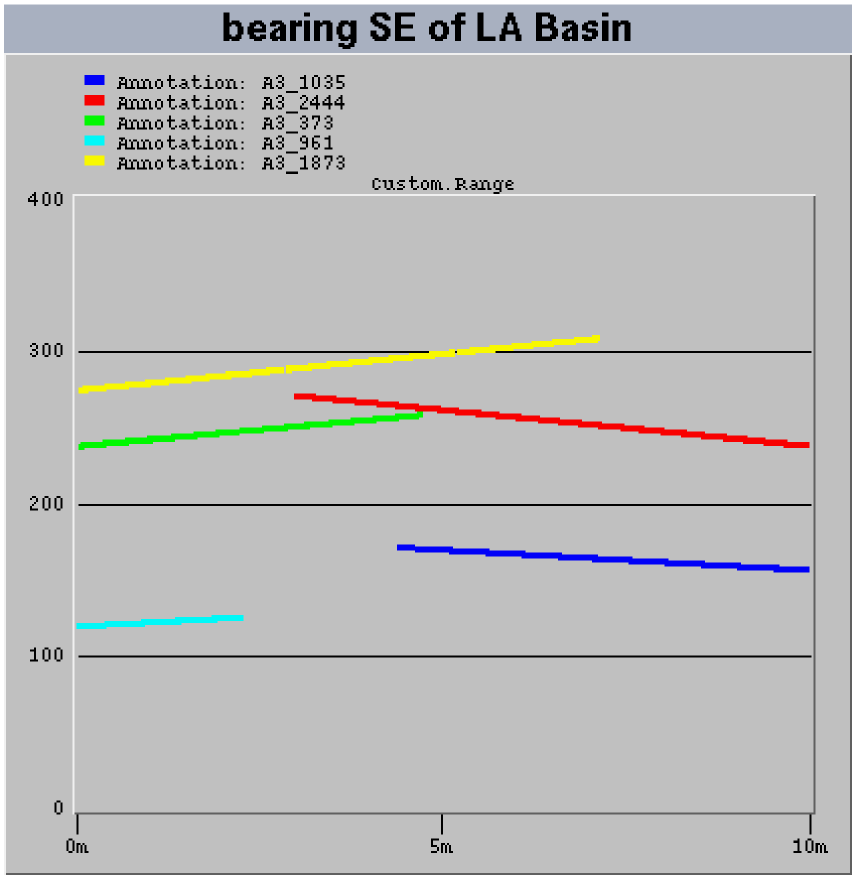


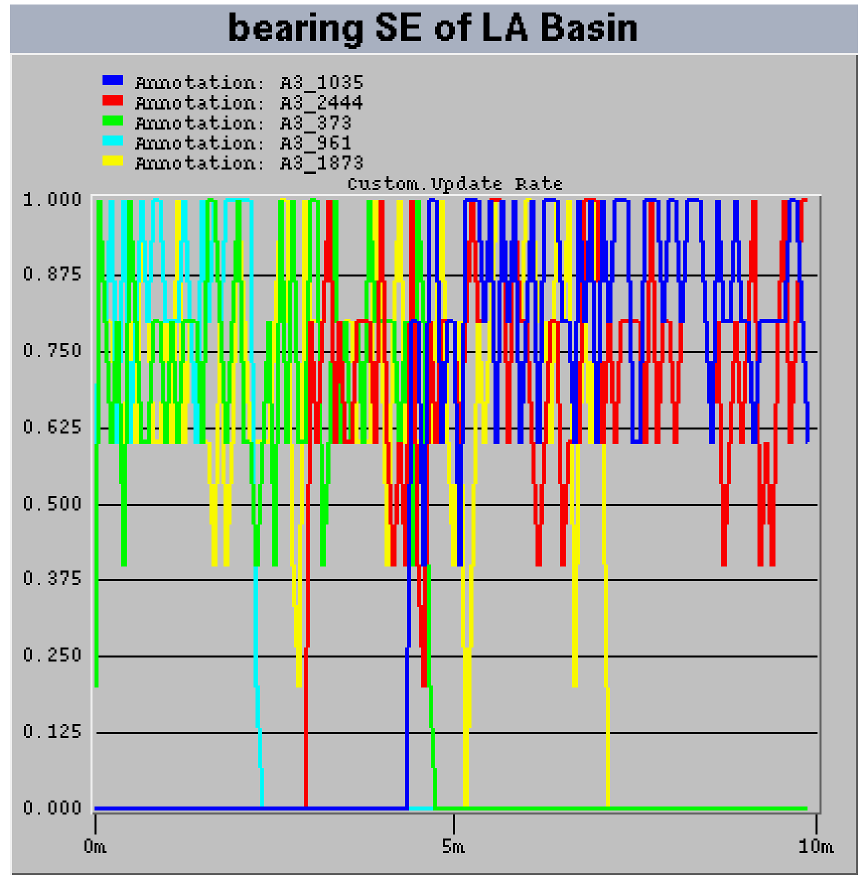
LA Basin 2020 Results
1090 MHz Arrival Rates



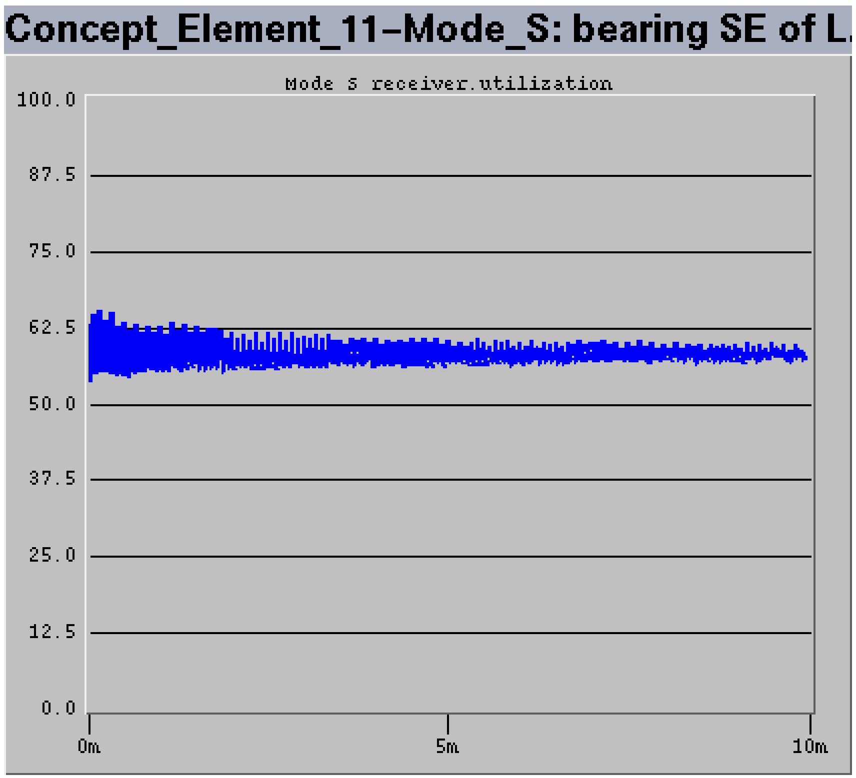
- Roughly 1250 ADS-B messages are received per second.
- Aircraft transmit at 6.2 messages per second
- Hence roughly 200 aircraft are visible to the receiver at any given time.

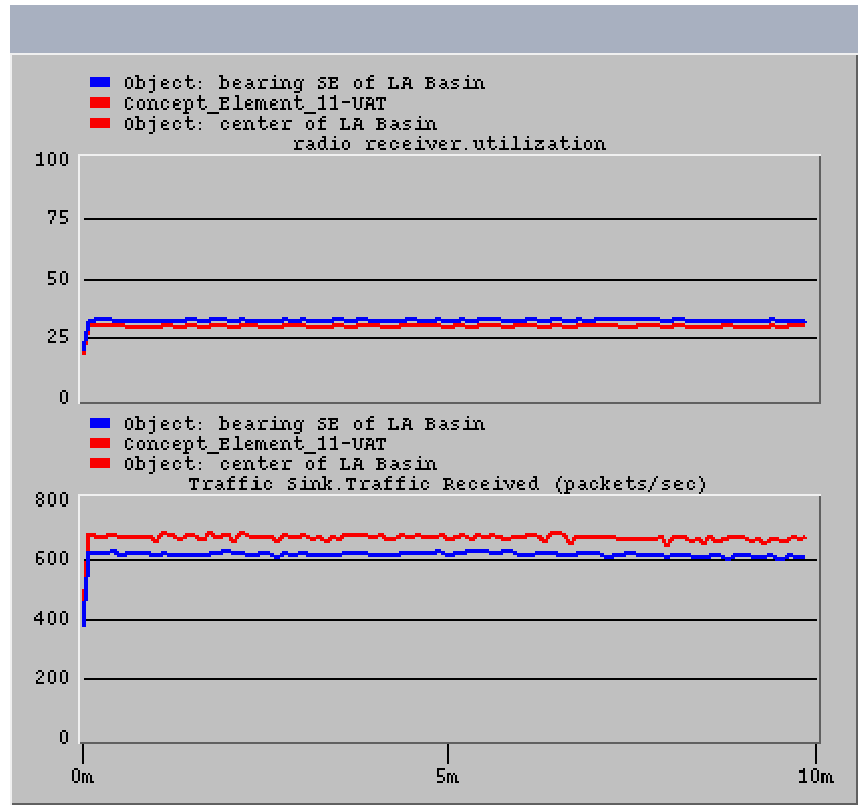
LA Basin 2020 Results
UAT Ranges & Update Rates



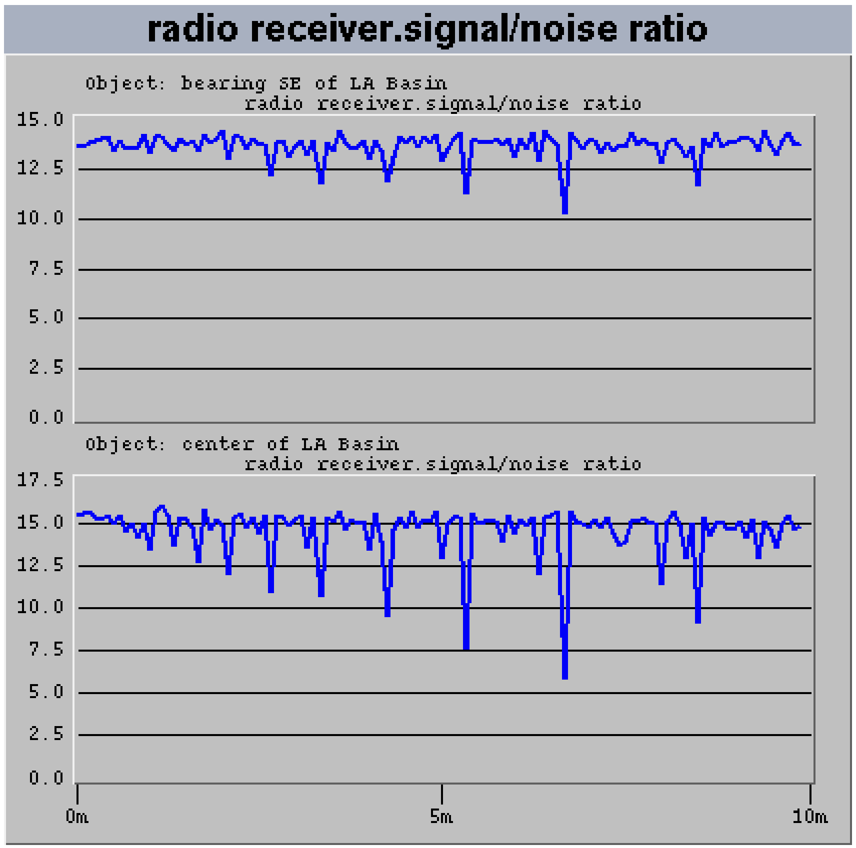


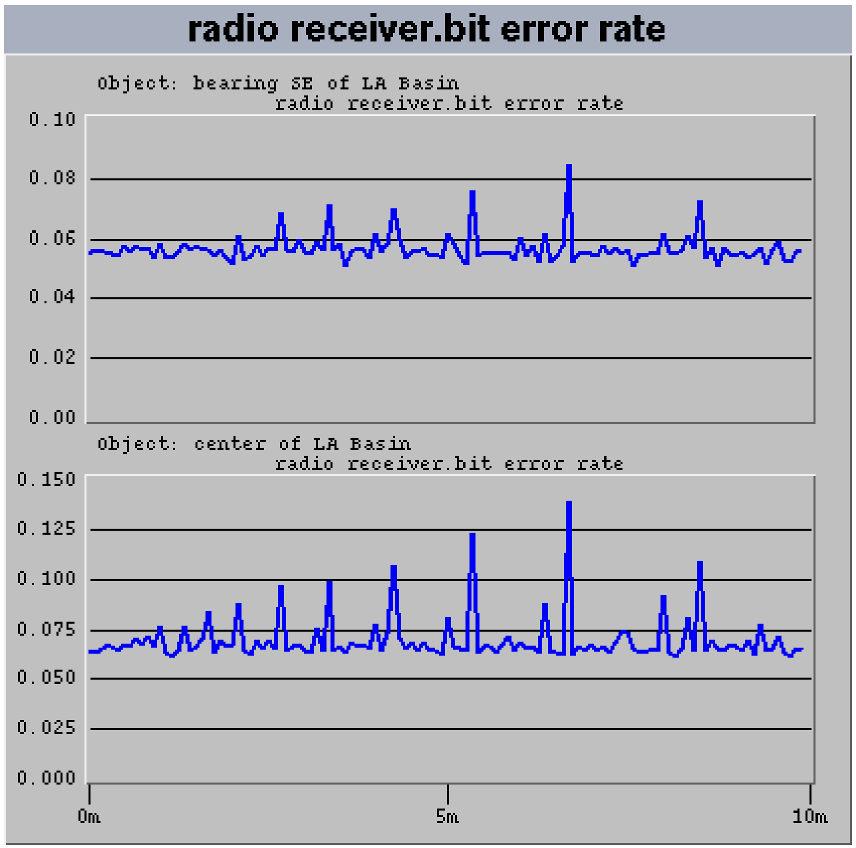
LA Basin 2020
Receiver Utilization





UAT SNR & BER


radio receiver.signal/noise ratio
Object: bearing SE of LA Basin
radio receiver.signal/noise ratio
15.0
12.5
10.0
7.5
5.0
2.5
0.0
Object: center of LA Basin
radio receiver.signal/noise ratio
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0m
5m
10m


radio receiver.bit error rate
Object: bearing SE of LA Basin
radio receiver.bit error rate
0.10
0.08
0.06
0.04
0.02
0.00
Object: center of LA Basin
radio receiver.bit error rate
0.150
0.125
0.100
0.075
0.050
0.025
0.000
0m
5m
10m

Assumptions and Limitations

- The true interference environment has been observed to be non-Gaussian based on MIT Lincoln Laboratories flight tests in the LA Basin in 1999. The approximation (multiple interferers within +/- 6 dB) was suggested to the author by Jon Bernays of the ATC group at MIT Lincoln Labs.
- The OPNET model used isotropic antennas instead of top/bottom mounted omnidirectional antennas specified in RTCA DO-181C and DO-282.
- If an aircraft is Mode S capable, the model assumed it would be interrogated as such. In reality older ATCRBS SSRs may interrogate it, increasing the ATCRBS traffic present.
- To improve simulation speed, TCAS interrogations and SSR interrogations were not explicitly modeled. TCAS replies assume a constant maximal interrogation rate, and the nature of SSR interrogations was based on the number of ground sites observed by MIT Lincoln Laboratories in their 1999 LA Basin study.

Assumptions and Limitations (cont.)

- Ground (zero altitude) receivers for ADS-B were not modeled, although they could have been.
- Although there was a transmission delay in addition to the free space propagation delay, and although simultaneous 1090 MHz messages within a node get queued for transmission, the onboard processing delay within the FMS was not modeled, due to a lack of information on how to do so.
- Interference from 1030 MHz transmissions were not included, because based on the OPNET interference model, they would not affect 1090 MHz reception.
- JTIDS transmission would interfere with UAT signals somewhat, but were not modeled, since military traffic is not always present, and since JTIDS uses a frequency hopping algorithm anyway.

Acknowledgments

- The work in this study was performed by Analex Corporation at NASA Glenn Research Center in Cleveland under Task 191 of the GESS Contract (NAS3-00145).
- The author wishes to thank Larry Bachman of Johns Hopkins APL for providing the LA Basin 2020 traffic file used in this study. The author also wishes to thank Jon Bernays of the Air Traffic Control Group at MIT Lincoln Laboratories for his valuable input on the nature of Mode S and 1090 MHz Extended Squitter ADS-B.

Conclusions and Future Directions

- 1090 MHz ES ADS-B performance in the TRACON is unacceptable in an environment including ATCRBS SSRs; however, the performance is somewhat improved in a 100% Mode S environment
- The ranges at which UAT ADS-B messages are received vary greatly, probably based on the local density of the aircraft. Aircraft within 12 LSBs of latitude or longitude do not interfere with each other, but aircraft whose 12 LSBs repeat (aircraft in different clusters) would interfere.
- The Signal-to-Noise Ratio for UAT exhibits more deep fades at the center of the LA TRACON resulting in higher bit error rates based on the CPFSK (MSK) modulation curve
- Future work would involve including JTIDS interference and more explicitly modeling the non-Gaussian nature of the interference environment