Communication and the Future of Air Traffic Management

ICNS Conference
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Agenda

- The Need for Change
  - NASA Virtual Airspace Modeling and Simulation Project (VAMS)
- Terminal Airspace Capacity Enhancement Concept (TACEC)
  - Overview
  - Operational Modes
- TACEC Communication Links
  - Initial Approach
  - Final Approach
- Communication Loading
- Conclusions

How long will your flight be delayed in 2022???

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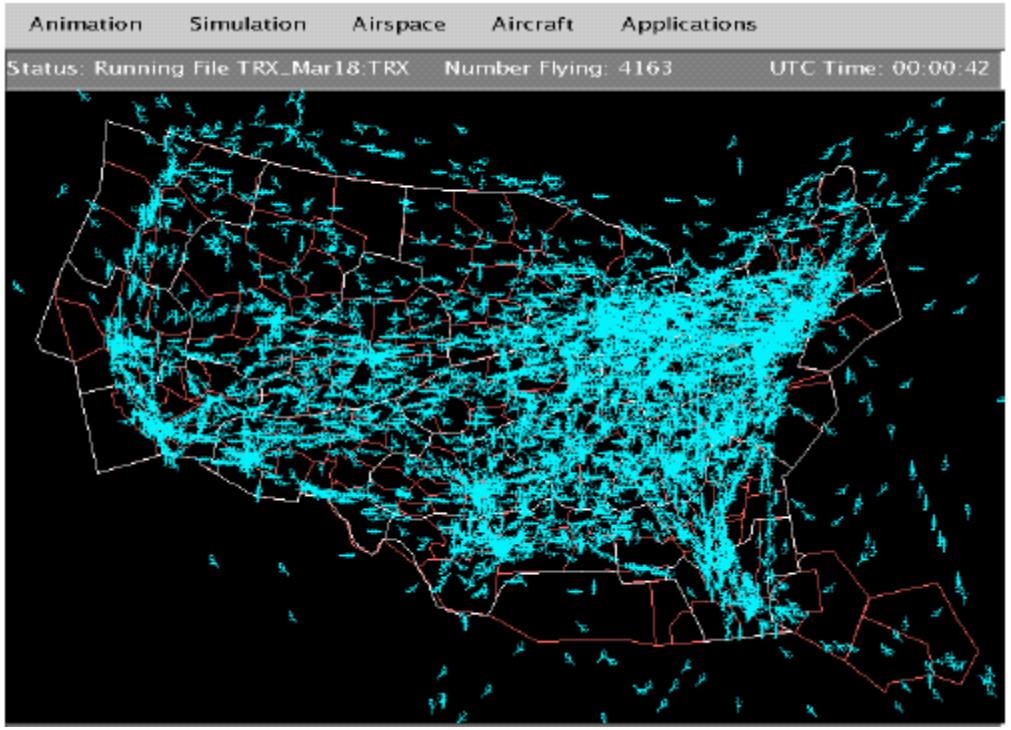
Today's National Airspace……..



..and the number of flights is expected to double in 10 years…..

Virtual Airspace Simulation and Modeling Program

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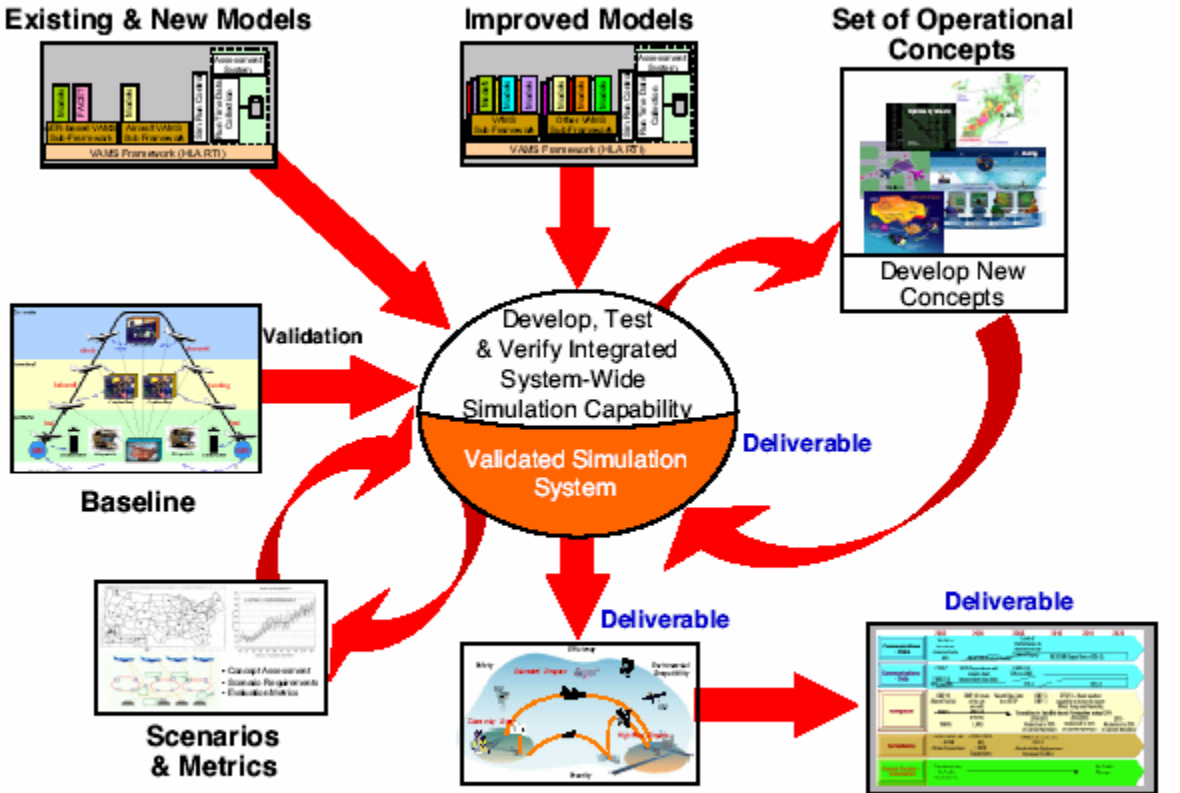

Terminal Area Capacity Enhancement Concept (TACEC)

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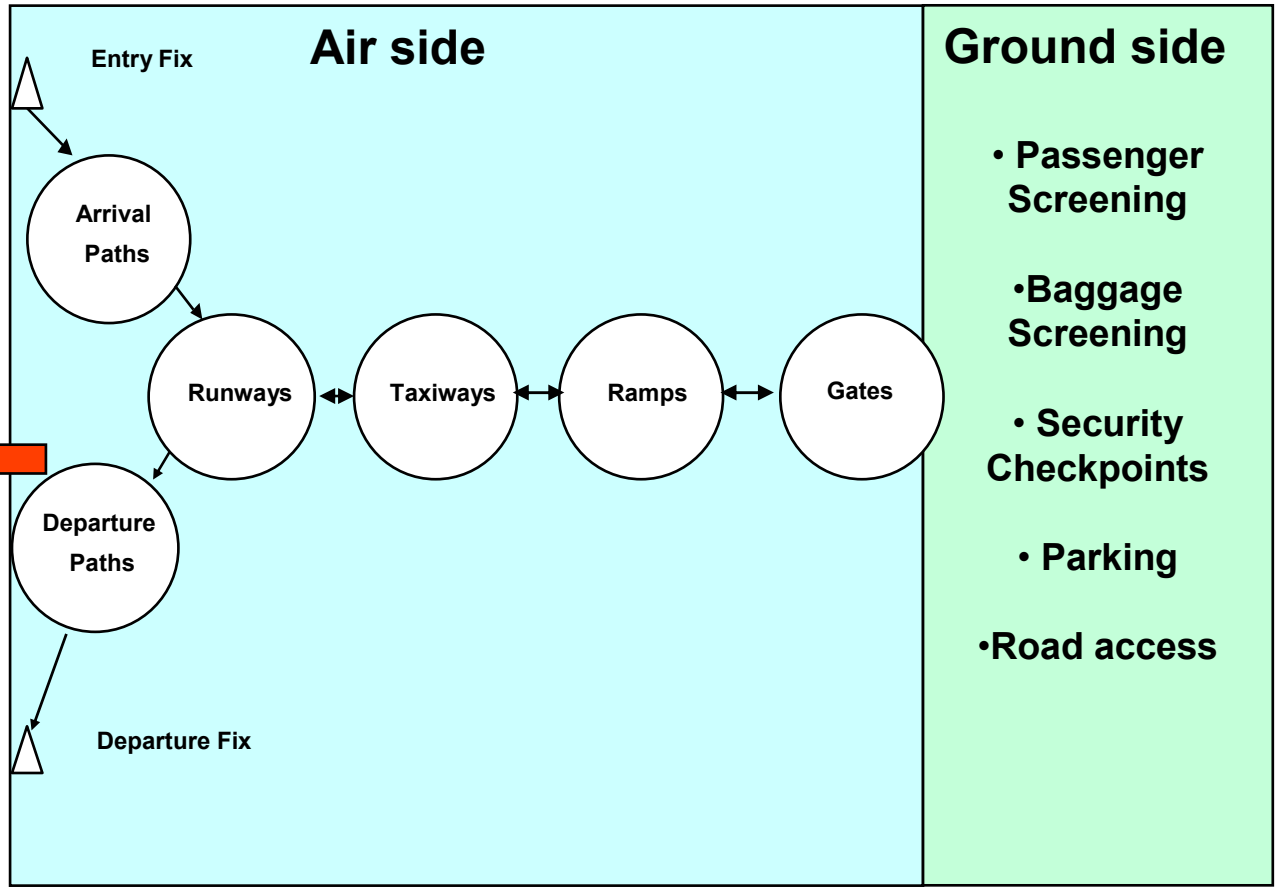
Raytheon's VAMS effort focuses on Terminal Area Constraints

Terminal Airspace

- Separation
- Aircraft Type
- Wake Vortex
- Weather

Airport Surface

- Number of runways
- Runway Occupancy
- Crossings
- Spot queues
- Gate Availability



TACEC Overview

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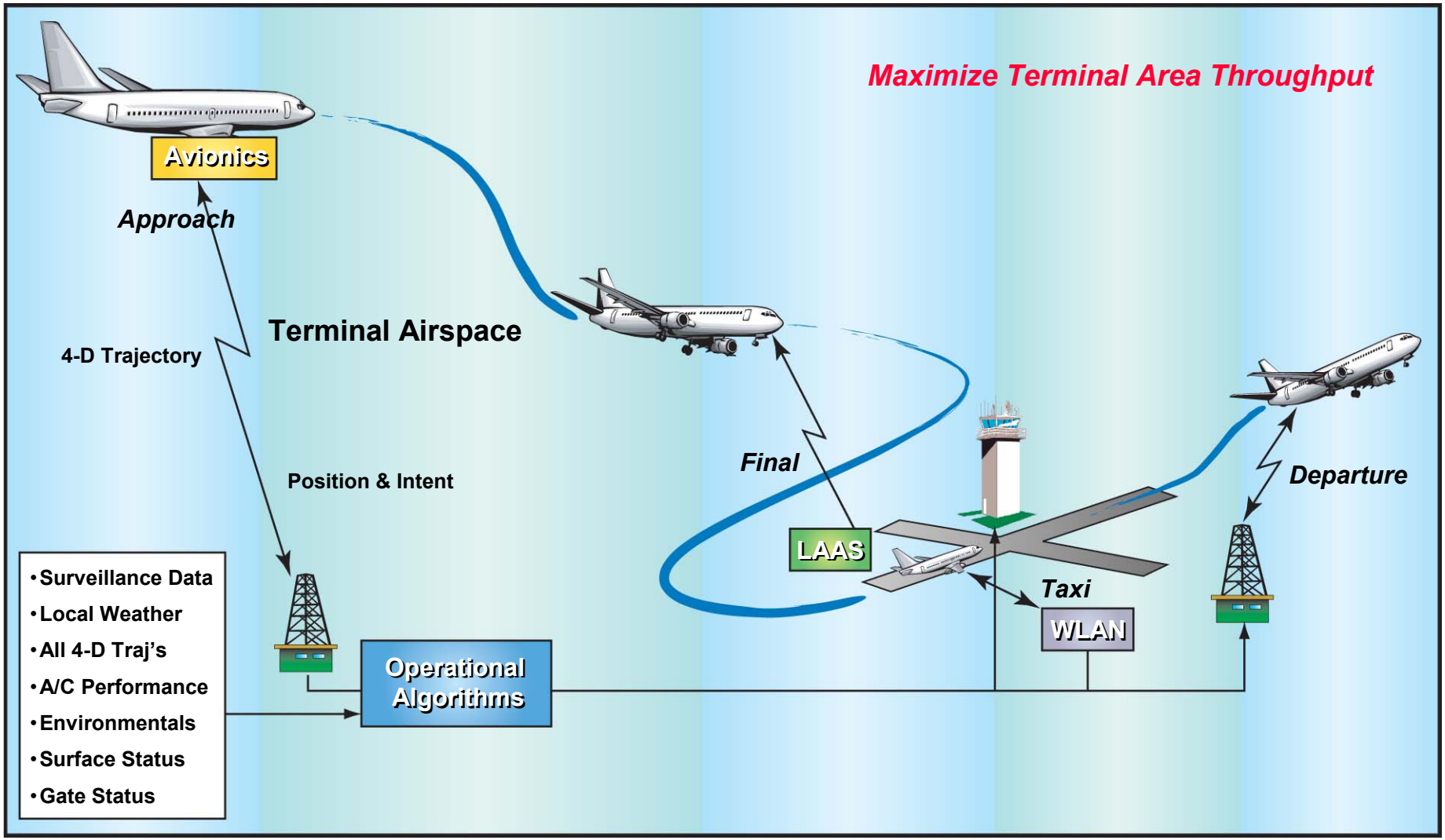

TACEC Core Ideas

Element	Projected Capacity Benefit	Comments
Precise 4D delivery of aircraft to runway threshold	10%-20%	Optimized arrival/departure operations
Reduced separation standards	No direct benefit	Necessary to support optimized 4D trajectories
Airborne self separation	No direct benefit	Element of redundancy in fully automated 4D trajectories
Parallel approach & landing (multi-aircraft)	Linear increase	Fundamental change in terminal operations
Optimized surface movement	Linear increase	Must accommodate parallel landings & gate availability

Fundamental limit on runway operations is In-Trail spacing required for wake vortex avoidance

Today's Wake Vortex Avoidance Solution

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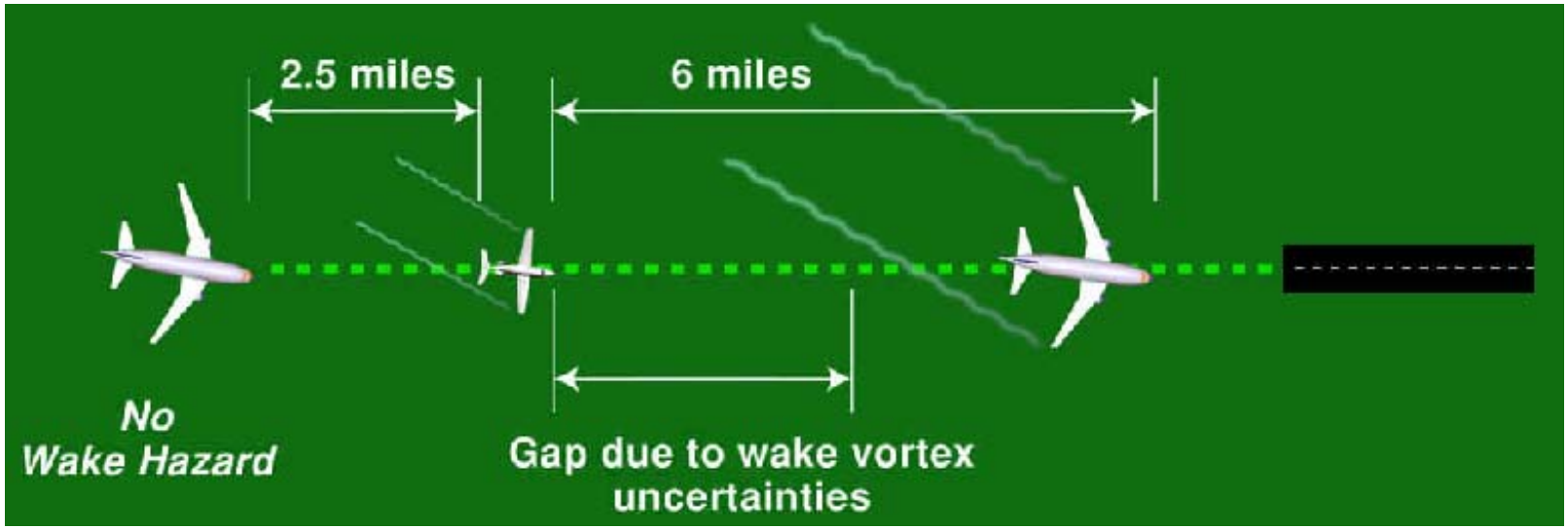
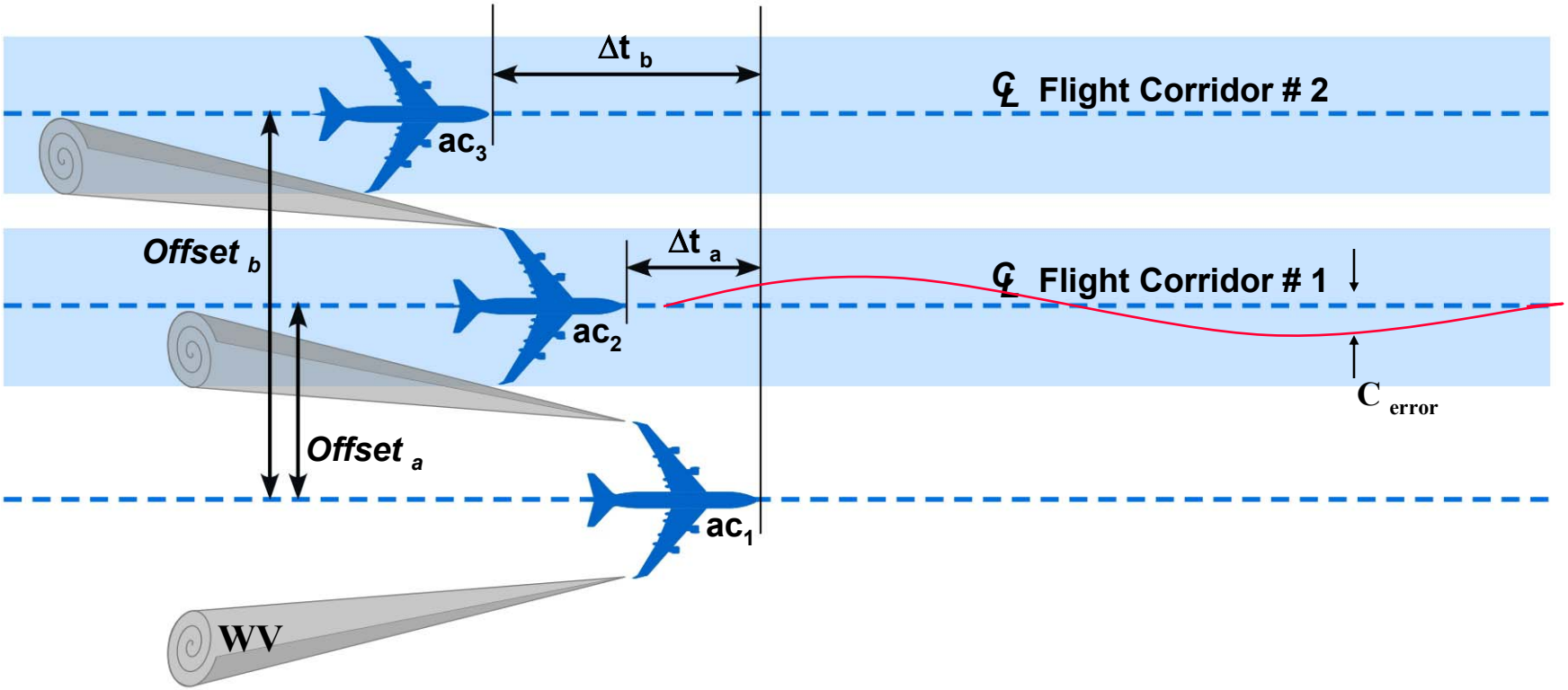


Following Aircraft Gap, (nm)	Lead Aircraft			
	Small	Large	B757	Heavy
Small	2.5	4	5	6
Large	2.5	2.5	4	5
Heavy	2.5	2.5	4	4

Flight Corridors[1] avoid WV by eliminating uncertainty



Offset $_a$ = WV (ac_1, t) + C $_{error}$ (ac_2, t)

Offset $_b$ = WV (ac_1, t) + WV (ac_2, t) + C $_{error}$ (ac_2, t) + C $_{error}$ (ac_3, t)

Note: WV is also dependent on atmospherics

1. Rossow, Vernon J, Use of Individual Flight Corridors to Avoid Vortex Wakes, AIAA Atmospheric Flight Mechanics Conf, August 2002

Implementation Requires Highly Reliable and Secure Data Link

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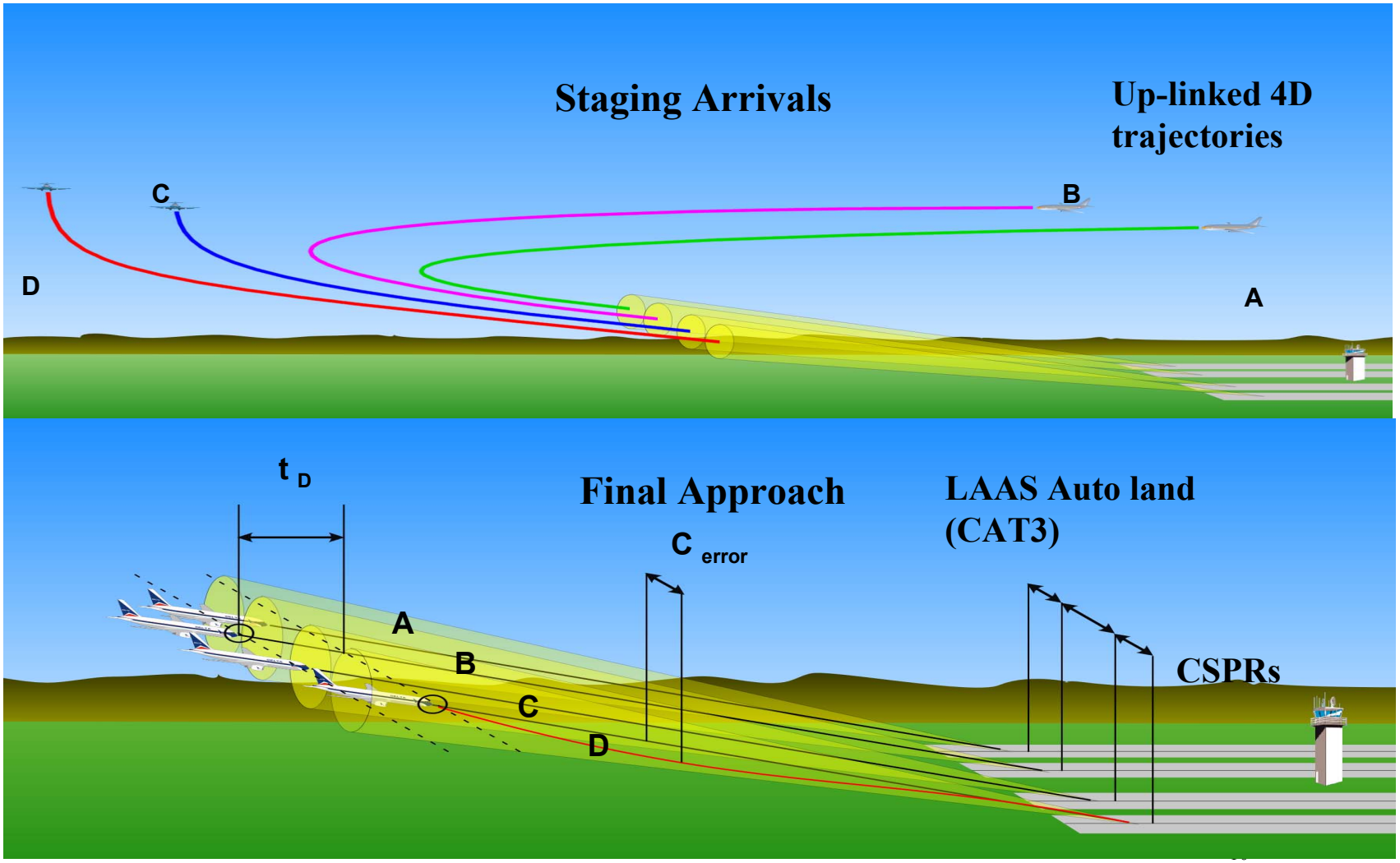
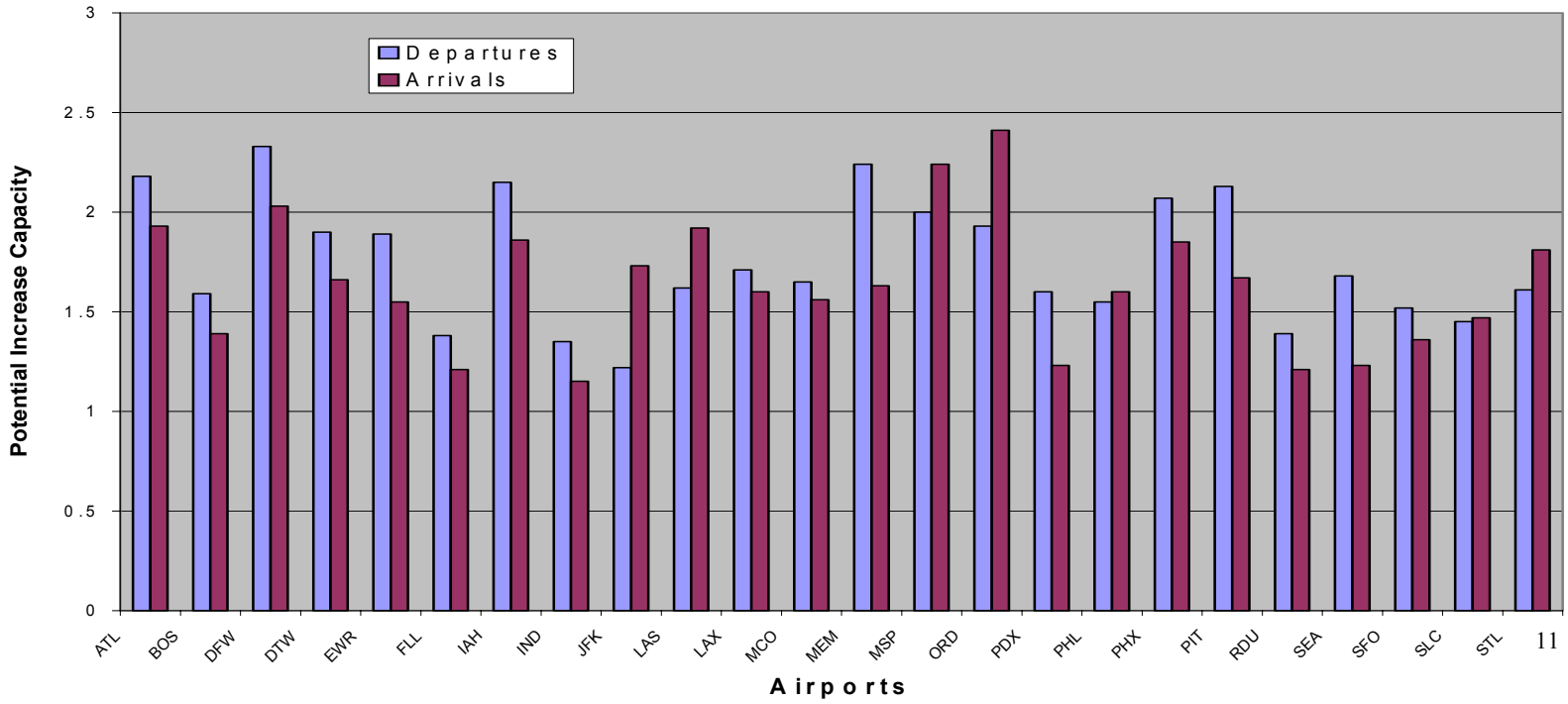


Initial Approach - Grouping Algorithm

- **Simultaneous Arrivals/Departures on very Closely Spaced Parallel Runways (CSPR) requires the ability to stage the arrival aircraft upon entering the Terminal airspace by:**
  - Establishing and Maintaining tracks on each flight using ADS-B
  - Grouping flights based on time, direction and aircraft type
- **24 airports identified as candidates for CSPR operation**



Initial Approach - Controlled Flight Path

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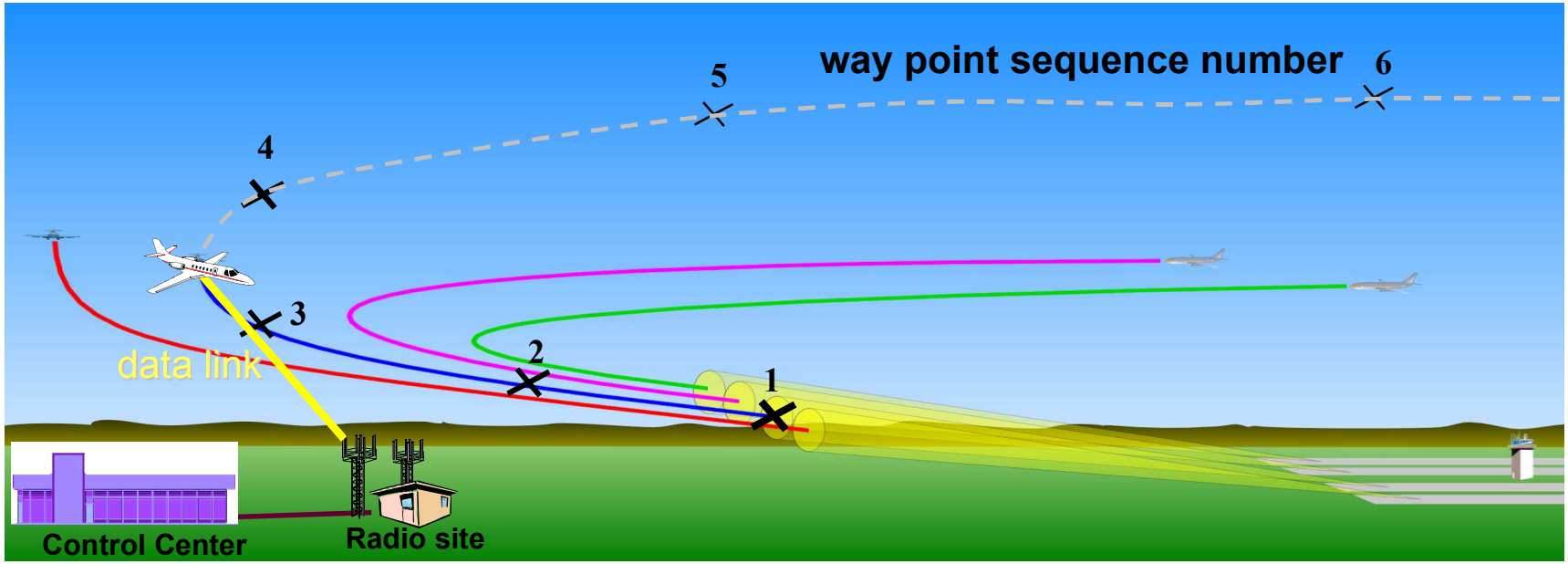

- **Each aircraft fly a controlled flight path during terminal area approach/departure**
  - Dynamic number of way points contingent upon traffic conditions, weather, etc.
  - 4-D way points (X/Y position, altitude & time) dynamically computed
  - Way point values uplinked every minute to each aircraft's flight control system

VDL Mode 3 Data Link enables greater use of automation and provides real-time access to and distribution of information

Link Performance Calculation Assumptions

- The following calculations are performed using the currently specified data link approaches of ISO-8208 (X.25) and ISO 8473.
  - Current avionics for VDL use these protocols for the data link implementations
- There is no inherent reason why in the future IPv6 could not be used as the link protocol.
  - Certification of the software supporting the protocol would need to be accomplished
- In all cases to reduce overhead on the limited bandwidth of the mobile link headers are (or would be) compressed effectively terminating constant values of the header at ground station and substituting a local index for the full address pairing.

Initial Approach - Data Rate Summary

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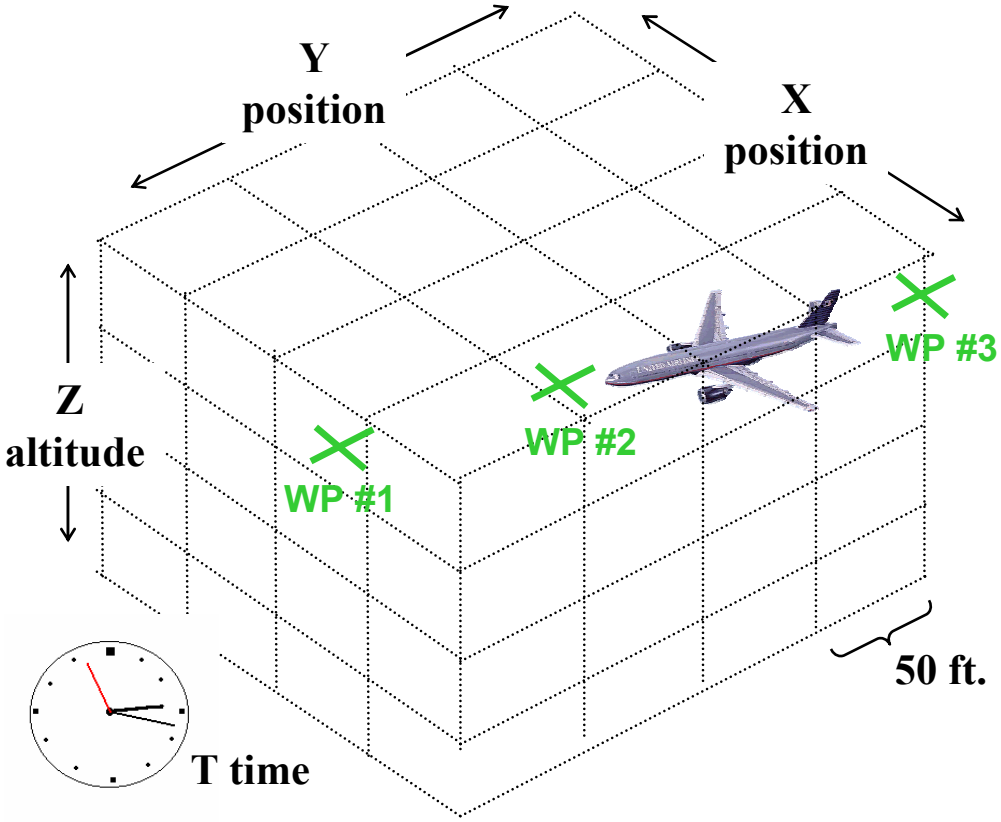

4 dimensional way points

Bit sizing per way point

16 - X position
16 - Y position
10 - Z altitude
20 - T time
10 - WP sequence #

72 bits or 9 bytes

Initial Approach - Data Rate Calculations (1 of 3)

- **Horizontal (X,Y) positions value**
  - Based on typical wake vortex uncertainty (500 ft), allocate 10% to LSB (50 ft)
  - Max range of +/- 100 Nautical Miles
  - Need 14 bits plus sign; allocate 16 bits each for X and Y
- **Vertical (altitude) position value**
  - Based on transition to final approach (500 ft), allocate 10% to LSB (50 ft)
  - Max altitude of 30,000 ft.
  - 10 bits allocated for altitude
- **Time value**
  - Nominal terminal aircraft speed (258 miles/hr) with 50 ft position LSB, requires time LSB $\approx$ = 0.1 seconds
  - Cover 30 hours to account for flights past midnight
  - 20 bits allocated for time
- **Way point sequence number**
  - 20 way points requires 5 bits, 10 bits makes final message length an even Byte

Initial Approach - Data Rate Calculations (2 of 3)

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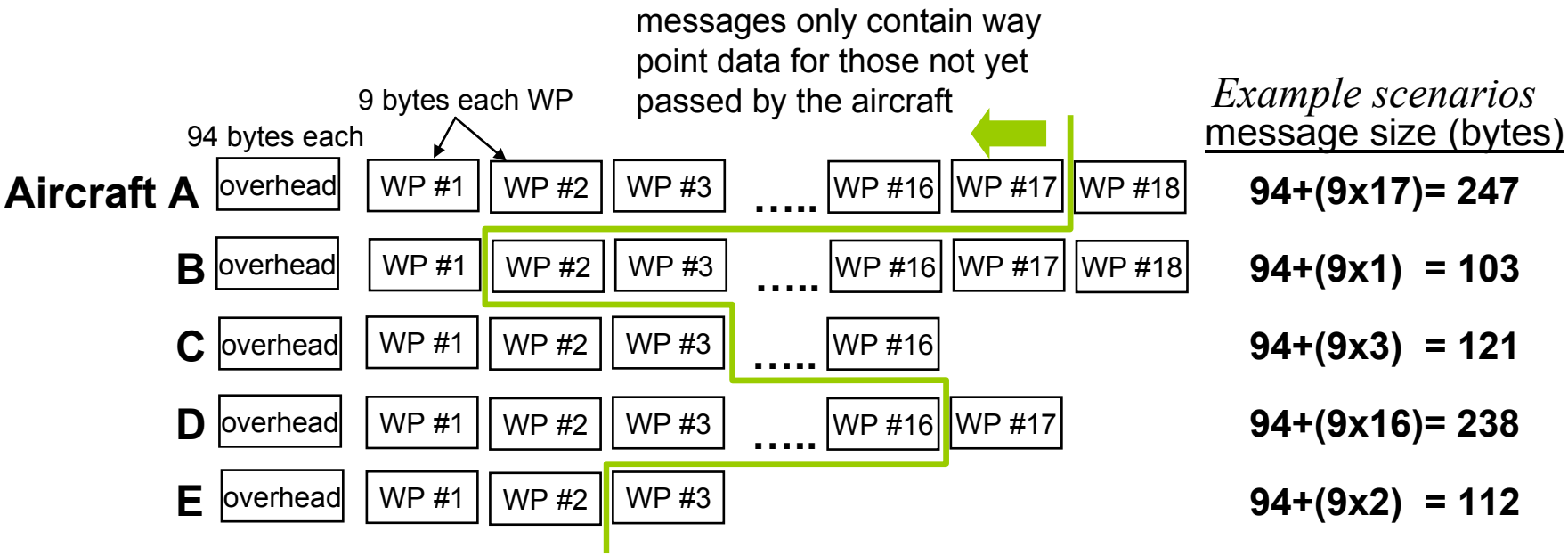
- **Protocol wrappers support an ISO 8208 data link connection = 91 bytes/message or CLNP = 78 Bytes/message**
- **Header/aircraft: (way point identifier = 2 bytes) + (field length = 1 byte) = 3 bytes**
- **Total number of way points required to route each aircraft is dynamic**



Initial Approach - Data Rate Calculations (3 of 3)

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- **Assumptions**
  - 3 parallel runway airport
  - 20 minutes to outer (approach/departure) waypoint @ 100 miles
  - 1 minute spacing between aircraft groups
  - 60 airplanes in initial approach
- **Max of 20 waypoints per aircraft, with each passing through a waypoint ≈ 1 min**
- **Average message will contain 10 waypoints**

01011001010101101101011001010110101010110101010101011001010

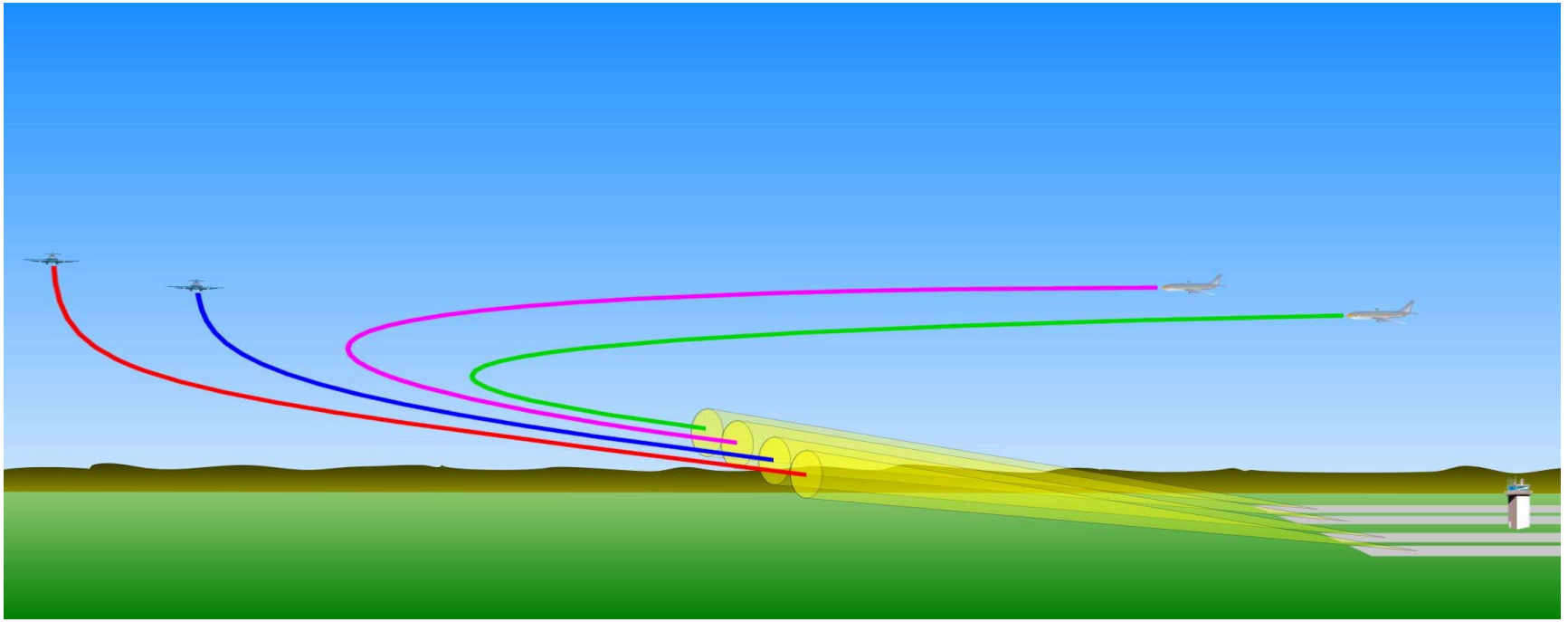
✔ Resultant load = **1.5 Kbps**

VDL Mode 3 Data Link capacity = 4.8 kbps in single D slot in a 2V2D configuration

Initial Approach - Analysis Conclusions

- **Maximum data load based on 60 arriving aircraft is only 30% of a single VDL Mode 3 control group capacity**
  - *System functionality fits within capability provided by VDL Mode 3*
  - *Departing aircraft have similar loading*
- **VDL Mode 3 maximum capacity is for 60 aircraft in a single 2V2D channel**
  - *The available 2nd channel on the same frequency accommodates departure traffic*
- **Uplink Message Start Opportunity every 120 msec. Typical queuing delay, 1 MAC cycle, for total latency of approximately 360 msec.**
  - *The downlink latency, which is much longer, is not relevant to this application*
  - *Downlink acknowledgement of uplink data handled through signaling channel*

Final Approach - Overview



- Close-control achieved thru LAAS and auto-land avionics
- Max of 30 aircraft during 5 minute Final Approach/Initial Departure

Final Approach - LAAS data link

- **LAAS uses a VHF TDMA-based broadcast link known as VDB**
- **FAS and differential reference points uplinked every 10 seconds, and differential corrections uplinked at 2 Hz**
- **Bandwidth allows for 95 unique Final Approach Segment (FAS) blocks, however number of unique Reference Path Data Selector codes limits actual number to 48**

LAAS/VDB supports TACEC Final Approach Comms

Additional TACEC Comms

- In addition to Initial and Final Approach flight plans TACEC uses:
  - ADS-B for surveillance of equipped aircraft
    - » Air to Ground, Air to Air
  - TIS-B for surveillance of non-equipped aircraft
    - » Air to Ground, Air to Air
  - Voice Comms
    - » Air to Ground, Ground to Air
  - Wind/Environmental
    - » Ground via ITWS

TACEC Data and Voice Messages

Air/Ground	Name	Kbits	Rate	Media	Phase
Air	4D Flight Plan ACFT	1.47	1/min	VDL Mode 3 Data	Initial
Air	TACEC Final Approach ACFT	0.74	2 Hz	VDB Datalink	Final
Air	TACEC ADS-B ACFT	0.11	1 Hz	1090 ES	Both
Air	TACEC ADS-B Rcv ACFT	16.5	1 Hz	1090 ES	Both
Air	TACEC TIS-B Rcv ACFT	11	1 Hz	1090 ES	Both
Air	TACEC Voice Aircraft	1	0.5/min	VDL Mode 3 Voice	Both
Ground	4D Flight Plan Ground	176.6	1/min	VDL Mode 3 Data	Initial
Ground	TACEC ADS-B Ground Station	16.5	1 Hz	1090 ES	Both
Ground	TACEC LAAS Ground	0.74	2 Hz	VDB Datalink	Final
Ground	TACEC TIS-B Ground to ACFT	0.11	1 Hz	1090 ES	Both
Ground	TACEC Voice Ground	1	0.5/min	VDL Mode 3 Voice	Both

TACEC Comm Loads

- **Communication Loads generated thru the NASA- Glen Research Center Future Aeronautical Subnet Traffic Emulator for Communications, Navigation , and Surveillance (FASTE-CNS)**
- **Traffic Load**
  - **100 mile Terminal Region**
  - **250 aircraft**
    - **120 Initial Approach/Final Departure**
    - **30 Final Approach/Initial Departure**
    - **100 non-equipped, General Aviation**

Media	Kbps	# of Freq	% Used
VDL Mode 3 Data	2.94	1	31
VDL Mode 3 Voice	0.64	1	7
VDB	1.48	1	5
1090 ES	16.6	1	5

Conclusions

- TACEC concept provides significant improvement to airport arrival and departure rates
- Much of the communication infrastructure is anticipated (still) to be in operation by the time of TACEC implementation
- Investigation to standardize format definitions and waypoint approach is underway

Questions?