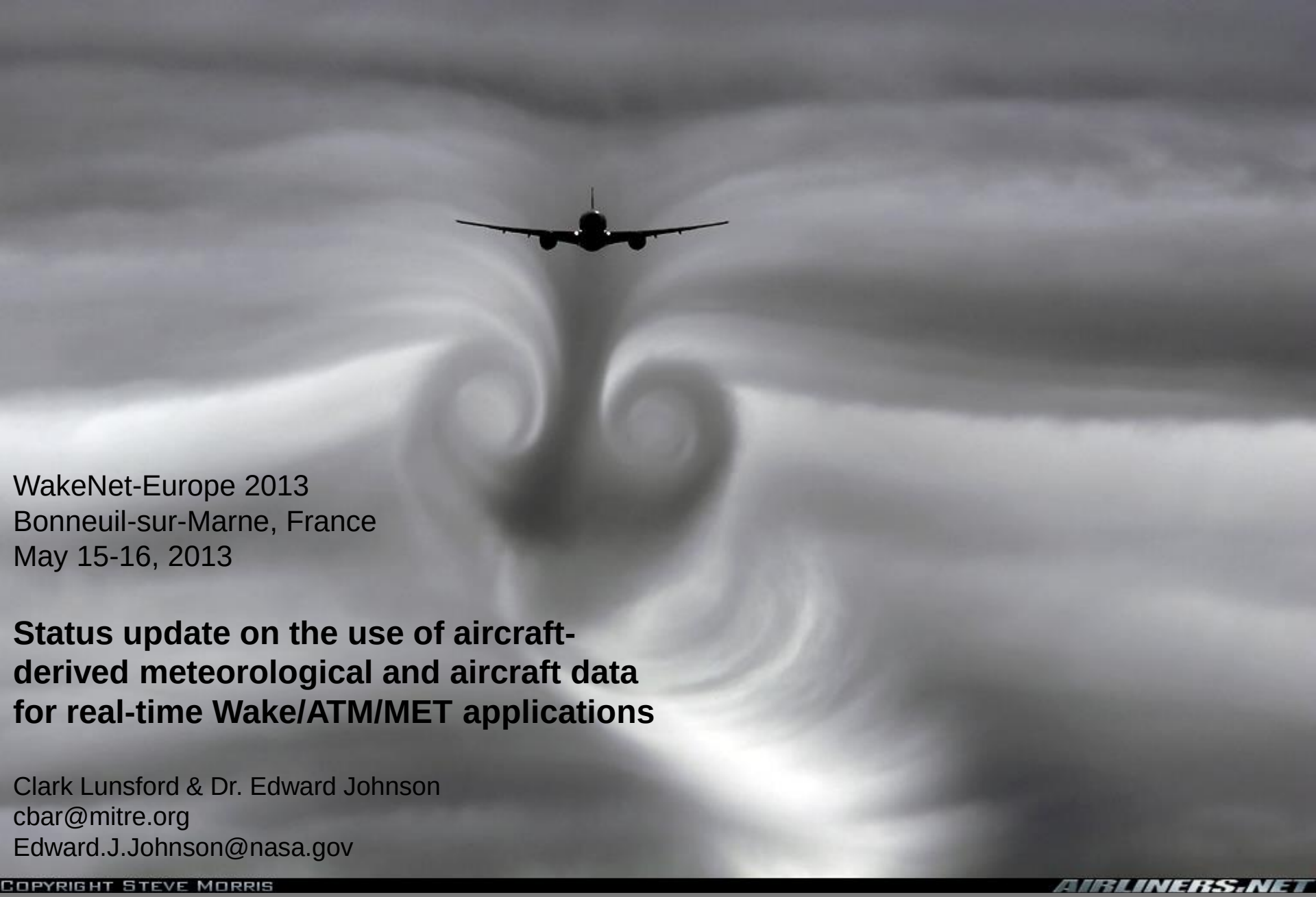

WakeNet-Europe 2013
Bonneuil-sur-Marne, France
May 15-16, 2013

Status update on the use of aircraft-derived meteorological and aircraft data for real-time Wake/ATM/MET applications

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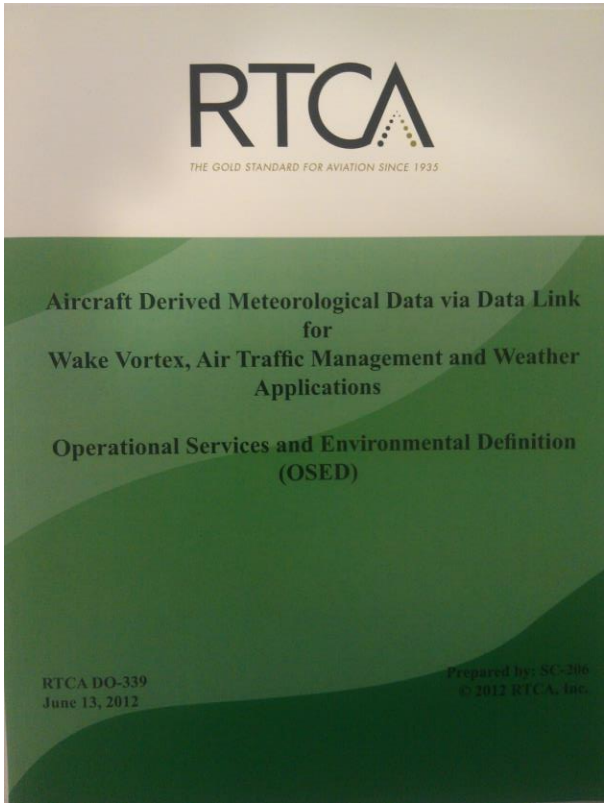
Outline

- Wake/ATM/MET OSED DO-339
- Data Elements for Link Agnostic Message Set
- Desired Characterization of the Atmosphere
- Coverage Model for Broadcast Data Links
- Data Link Analyses
- Next Steps

DO-339 Wake/ATM/MET OSED Published by RTCA June 2012

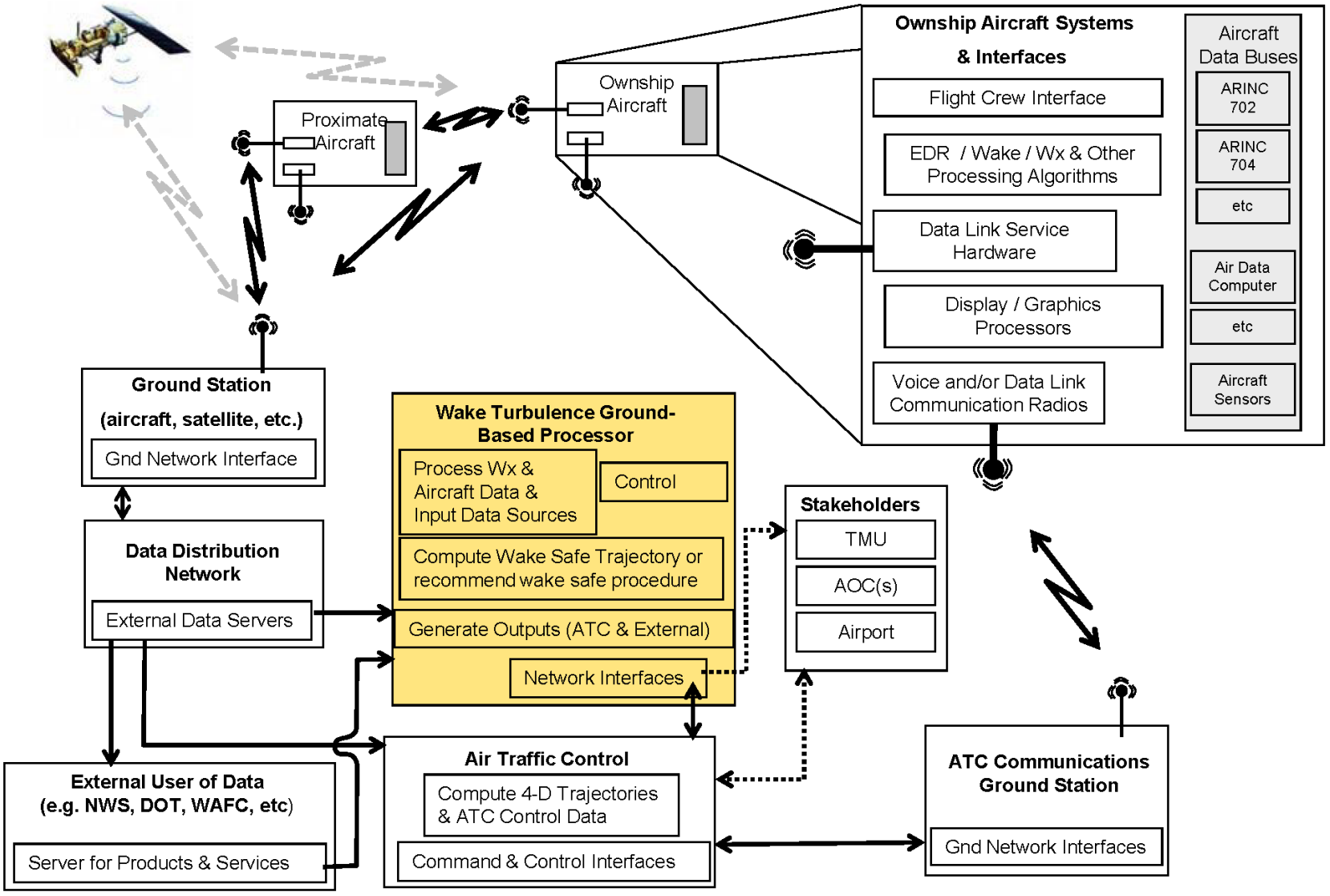
DO-339 defines a concept of operations for transmitting aircraft-derived meteorological data in real-time to enable a wide range of applications in the areas of wake turbulence, air traffic management and meteorology.



The RTCA first published the concept in 2009 as additional non-normative information for the consideration of industry as Appendix V to DO-260B and Appendix S to DO-282B. Publication of DO-339 puts the RTCA and industry on a formal path towards development of system requirements and standards to implement the proposed capabilities in the national airspace system.

The OSED describes the specific data to be transmitted, including bit count and timing; addresses acquisition of required data from standard data labels on standard aircraft data buses as well as provisions for participation by aircraft not equipped with data buses and/or flight management systems; discusses constraints under which the proposed service must operate; and provides an overview of potentially applicable performance standards, error handling, system safety and system security topics.

Notional System Architecture for Air/Ground Wake Turbulence Applications



Desired Characterization of the Atmosphere

Data Element	Airport and Terminal Maneuvering Area	En Route
Atmospheric Data Elements Wind Speed Wind Direction Static Pressure Static Temperature Eddy Dissipation Rate Humidity/ Water Vapor	Every 50’ of altitude Every 1 NM in level flight	Every 500’ of altitude Every 5 NM in level flight
Hazardous Weather Data Elements Wind Shear Microburst Icing Peak Turbulence	On Condition	
Aircraft Surveillance Data Elements Position Altitude Track Heading Vertical Rate True Airspeed Mach Number	Transmitted at 1 Hz (rates suitable for use in real time decision support tools and for video depiction)	
Aircraft Data Elements Aircraft ID Aircraft Type Weight Wing Span Aircraft Configuration Wake Vortex Initial Circulation Strength	Transmitted in conjunction with atmospheric data elements	

Desired spatial and temporal resolutions are achieved by combining routinely transmitted data messages from multiple aircraft

Capacity enhancing wake turbulence solutions are most often needed in dense air traffic environments

Complete List of Data Elements (Including Surveillance Data) Slide 1 of 2

Data Field	# of bits	Range	LSB/Comments	Desired Reception Period (seconds)
Measurement Time (UTC)	17	0..86,400	Seconds	1
Aircraft/Measurement Position – Latitude Status	1	0=no data, 1=current data		1
Aircraft/Measurement Position – Latitude	20	0..90		1
Aircraft/Measurement Position – Longitude Status	1	0=no data, 1=current data		1
Aircraft/Measurement Position – Longitude	20	0..180		1
Aircraft/Measurement Position – Pressure Altitude Status	1	0=no data, 1=current data		1
Aircraft/Measurement Position – Pressure Altitude	12	-1000 – 50175 ft	25 or 100 ft See Note 6	1
Aircraft speed Status	1	0=no data, 1=current data		1
True Airspeed	20	X - XX Knots		1
Aircraft Heading Status	1	0=no data, 1=current data		1
Aircraft Heading	10	0…359 degrees True	1 degree See Note 1	1
Unique aircraft identifier	24			1
Aircraft Type (ICAO type or Emitter Category)	1	0=no data, 1=current data		1
Aircraft Type (ICAO type or Emitter Category)	ICAO X or Emitter 3	NA	NA	1
Wind Data Status	1	0=no data, 1=current data		3
Aircraft roll angle	7	0..90 degrees	1 degree	3

Data Field	# of bits	Range	LSB/Comments	Desired Reception Period (seconds)
Wind Speed	8	0..255 knots	1 knot	3
Wind Direction	9	0…359 degrees	1 degree See Note 1	3
Static Air Temperature Status	1	0=no data, 1=current data		10
Static Air Temperature	9	-128..127.5 degrees C	0.5 degrees C	10
Average Static Air Pressure Status	1	0=no data, 1=current data		10
Static Air Pressure	11	0..2047 hPa	1 hPa See Note 2	10
Turbulence Status	1	0=no data, 1=current data		10
Average Turbulence Metric (EDR1/3)	8	0..1.27 in EDR1/3 units	0.005 in EDR1/3 units. See Note 8	10
Humidity/water vapor Status	1	0=no data, 1=current data	See Note 5	20
Humidity/water vapor	7	0..100%	100/127 percent, See Note 5	20
Configuration Status	1	0=no data, 1=current data	See Note 3	20 nominal 10 on status change
Flaps Setting	2	0=no data 1=flaps retracted 2=flaps partial 3=flaps landing	See Note 3	20 nominal 10 on status change
Wing Span	4	0-15		20
Aircraft Weight Status	1	0=no data, 1=current data		20
Aircraft Weight	8	See note	See note 4	20
Turbulence Status	1	0=no data, 1=current data		20 nominal 10 on triggering event
Peak Turbulence Metric ($EDR^{1/3}$)	8	0..1.27 in $EDR^{1/3}$ units	0.005 in $EDR^{1/3}$ units. See Note 8	20 nominal 10 on triggering event

Complete List of Data Elements (Including Surveillance Data) Slide 2 of 2

Data Field	# of bits	Range	LSB/Comments	Desired Reception Period (seconds)
Icing Status	1	0=no data, 1=current data		20 nominal 10 on triggering event
Icing Hazard Metric	2	00=none, 01=light 10=moderate, 11=severe	See note 7	20 nominal 10 on triggering event
Wake Vortex Status	1	0=no data, 1=current data		20
Wake Vortex Initial Circulation Strength	6	0-63, representing a range of 50-800 m^2/sec in 12.5m^2/sec increments	12.5m^2/sec	20
Windshear/Micro burst Status	1	0=no data, 1=current data		20 nominal 10 on triggering event
Windshear or Microburst Indication	2	00= none 01=windshear 10=microburst		20 nominal 10 on triggering event
Airspeed Change Sign Bit	1	0=gain, 1=loss		20
Airspeed Change Magnitude	3	0-7, representing a range from 5-40 knots in 5 knot increments	5 knots	20
Volcanic Ash Status	1	0=no data, 1=current data		20 nominal 10 on triggering event
Volcanic Ash Hazard Metric	2	00=none, 01=light 10=moderate, 11=severe	See note 8	20 nominal 10 on triggering event

Notes:

1. Vertical Wind Speed is a desired parameter for some potential applications. However the “noise” associated with measurements of this parameter may diminish its usability
2. Barometric pressure altitude is currently included in DO-260B and may provide the required atmospheric pressure data. Static air pressure may not be necessary should further analysis determine that barometric pressure altitude is sufficient.
3. Configuration data is primarily to indicate aircraft acceleration or deceleration status rather than wake characteristics.
4. ARINC Label 075 in the avionics conveys the aircraft’s weight as a 16-bit field employing 40-pound increments. Encoding schemes have been developed that can report aircraft weight within 4% for all aircraft types using fewer bits. The least significant bit resolution may vary from 40 lbs for light aircraft to 4000 lbs for heavy aircraft. If the actual weight to be encoded exceeds the encoding weight maximum, the maximum encode-able weight should be used. Aircraft not equipped to report weight should statically report maximum takeoff weight.
5. Humidity/water vapor is a primary meteorological parameter used to characterize the state of the atmosphere. Current numerical models for wake turbulence do not utilize this parameter, however due to increasing deployment of sensors and improved data collection, future models may incorporate this parameter to forecast wake vortex dissipation and movement. Standards work in this area may influence how and to what level of resolution humidity/water vapor should be reported.
6. ICAO Annex 10 Volume IV July 2007 specifies 25 ft or 100 ft increments depending on the value of Q.
7. If future icing sensors are able to deliver better resolution of icing information such as accretion rate and type of ice, then more bits may be required.
8. A group has been formed to establish standards for reporting EDR. Here, 8 bits are reserved. However, lesser resolutions may be deemed acceptable.

Many required data elements are already available through existing data link services (e.g. ADS-B & MDCRS). However, data transmission rates may not support real-time applications.

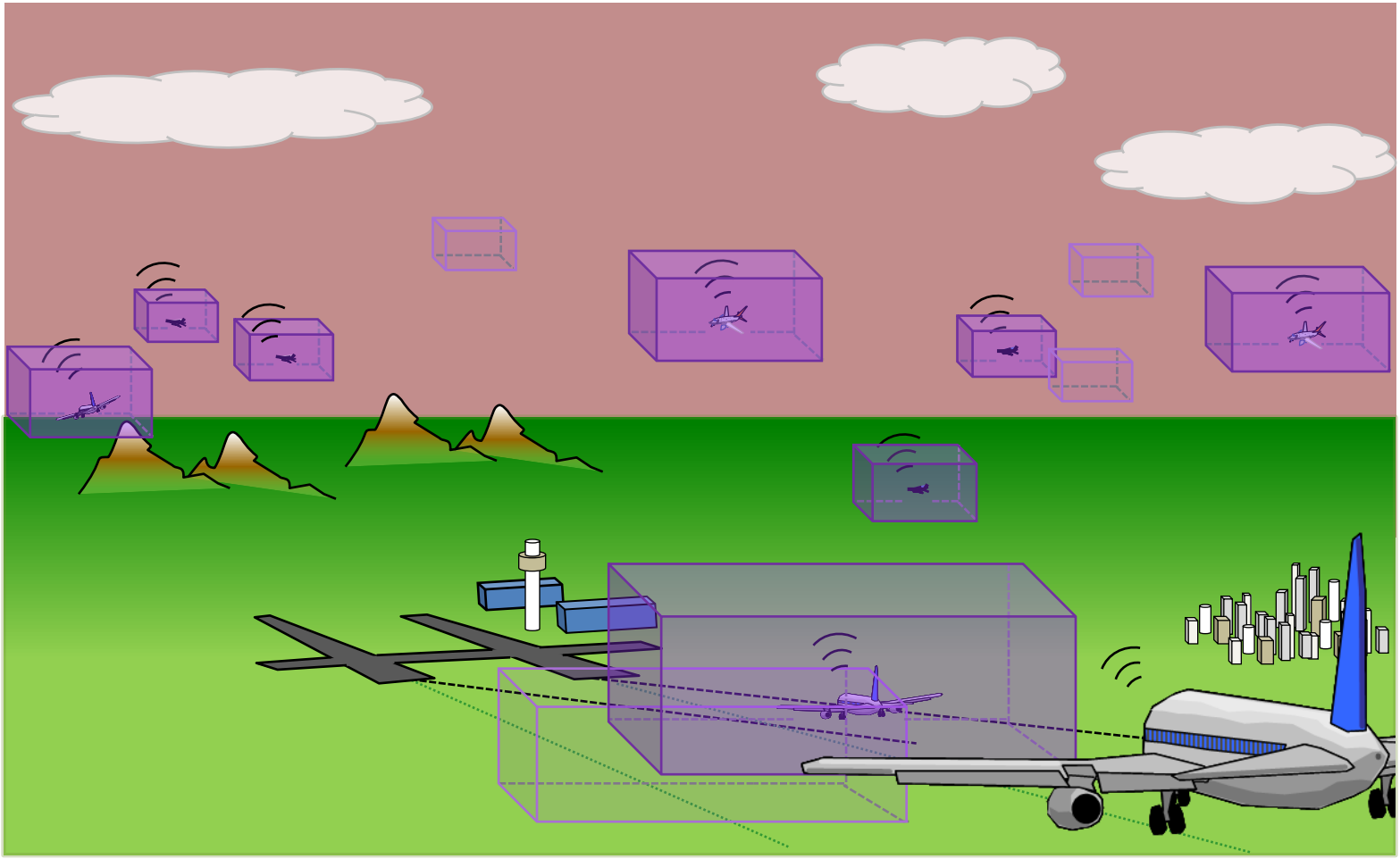
Aircraft Reporting in Terminal Area (ARITA)
Model Experiment and Results for Broadcast Coverage Analysis

Laurence Audenaerd, Ph.D.
MITRE Corporation

ARITA Model: How much coverage do we get?

Objective: Identify the broadcast frequency of Aircraft-based Meteorological Data (MET) for adequately covering terminal area operations for supporting spatial-data dependent operations, e.g., weather-based trajectory operations for wake spacing reductions, weather hazard alerting, or continuous descent approach procedures.

Aircraft broadcast MET data at a specified frequency
Eventually, information becomes stale and validity fades
Captures information about small regions for a given duration



Courtesy MITRE Corporation

Modeling Assumptions and Experimental Design

- **Meteorological Data (MET)**
  - Broadcast Frequencies (Messages/Min): 3, 6, 10, 20, 60
  - Message Persistence, i.e., valid for: 5 minutes
- **Equipage Rates for Data Broadcast**
  - Equipage Range (% of Traffic): 20%, 40%, 60%, 80%, 100%
- **Arrival Demand Density**
  - Traffic Cases (Arrivals/Hour): 15, 40, 65
  - Arrival schedule is modeled as a Poisson Process
- **Definition of Coverage** – Spatial range along the glide path for which a specific message is valid
    - Assumed to be 50 ft of vertical on approach path
    - Approach path begins at 6000 ft (approximating a 20 mi final)

Selected Results

Reports per min	Sec per report
3	20
6	10
10	6
20	3

Vertical Resolution	50 ft				
Coverage Results					
Traffic					
15	Equipage				
Freq	20%	40%	60%	80%	100%
3	5.1%	11.6%	14.4%	19.4%	21.4%
6	9.2%	19.2%	27.3%	31.7%	37.8%
10	17.9%	29.2%	34.6%	49.1%	53.8%
20	27.8%	38.5%	57.7%	65.0%	77.0%
60	28				77.8%
Traffic					
40	Equi				
Freq	20				100%
3	13				45.2%
6	23				61.1%
10	35				84.4%
20	55				95.6%
60	56				98.8%
Traffic					
65	Equipage				
Freq	20%	40%	60%	80%	100%
3	21.7%	36.1%	45.3%	52.1%	58.3%
6	33.4%	51.8%	60.7%	67.0%	70.6%
10	52.2%	74.4%	82.4%	86.9%	90.1%
20	75.0%	89.9%	97.2%	99.0%	99.9%
60	74.7%	91.8%	96.4%	98.8%	99.9%

Wind data broadcast at either 1 per sec or 3 per sec covers > 95% of glide slope in moderate traffic loads

Coverage = 1 – Uncovered Periods

- Periods with Similar Average Equipment (below)Show Similar Coverage
- With low frequency/small equipage, sizable area is still covered

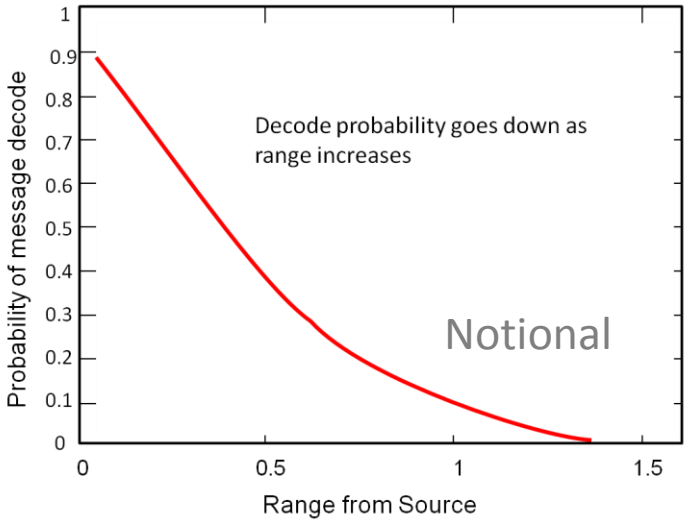
	Percent of Fleet Equipped				
Traffic	20%	40%	60%	80%	100%
15	3	6	9	12	15
40	8	16	24	32	40
65	13	26	39	52	65

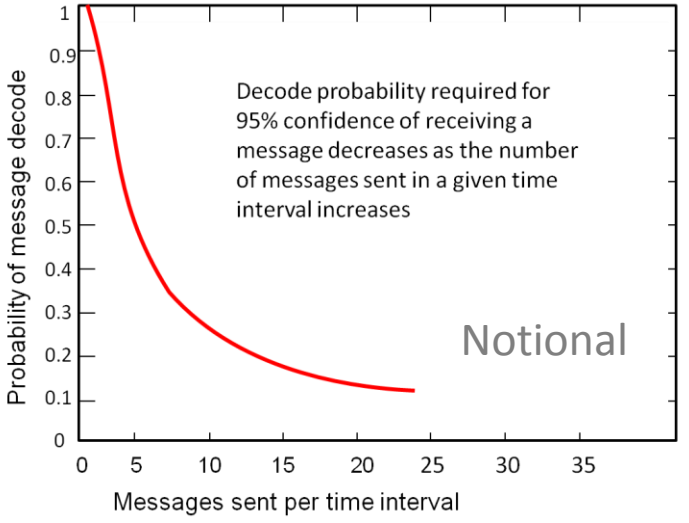
Analysis of Candidate Data Links

Study of 1090ES ADS-B Data Link

- ADS-B data links are attractive candidates to carry real-time data for Wake/ATM/MET applications but technical and programmatic issues must be resolved

- Small Independent study of 1090ES data link underway:
  - 1090ES more constrained than other ADS-B links (e.g. UAT)
  - Must address additional spectrum loading due to Wake/ATM/MET messages
  - Need to consider range limitations in projected high density (e.g. 2025) traffic scenarios
  - Assess impacts to existing and planned messages
    - Options identified to send wind data with no additional spectrum utilization
    - However, decode probably for existing messages is impacted
  - Must identify specific cases (if any) that could result in ICAO average squit rate limit being exceeded
  - Study is coordinated with FAA 1090ES spectrum utilization group

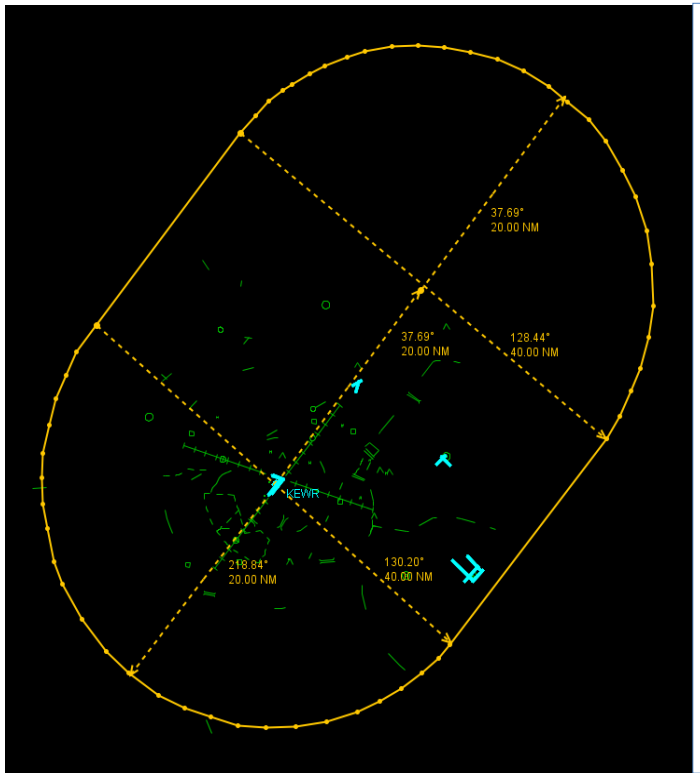


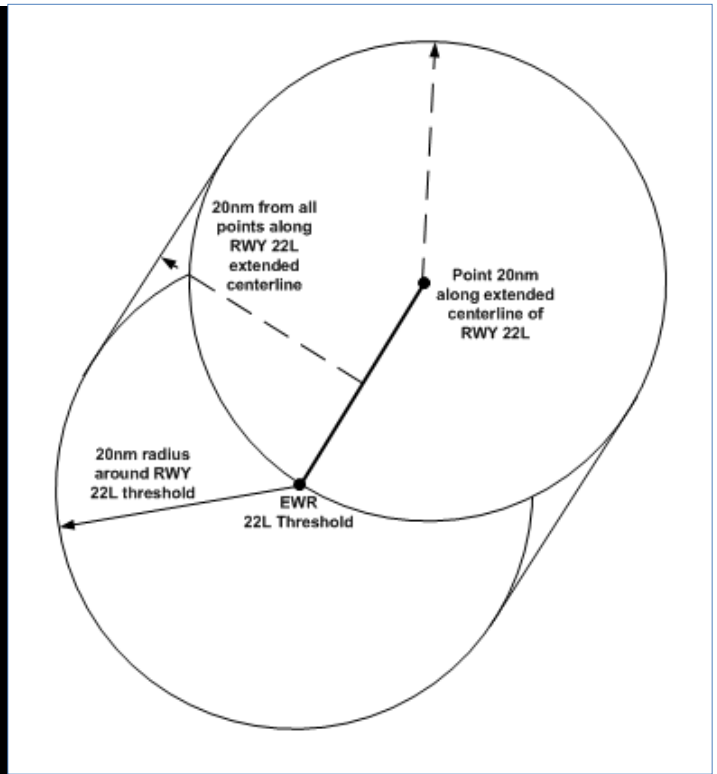


Single Airport Use Case Developed for Analysis with OPNET Toolset

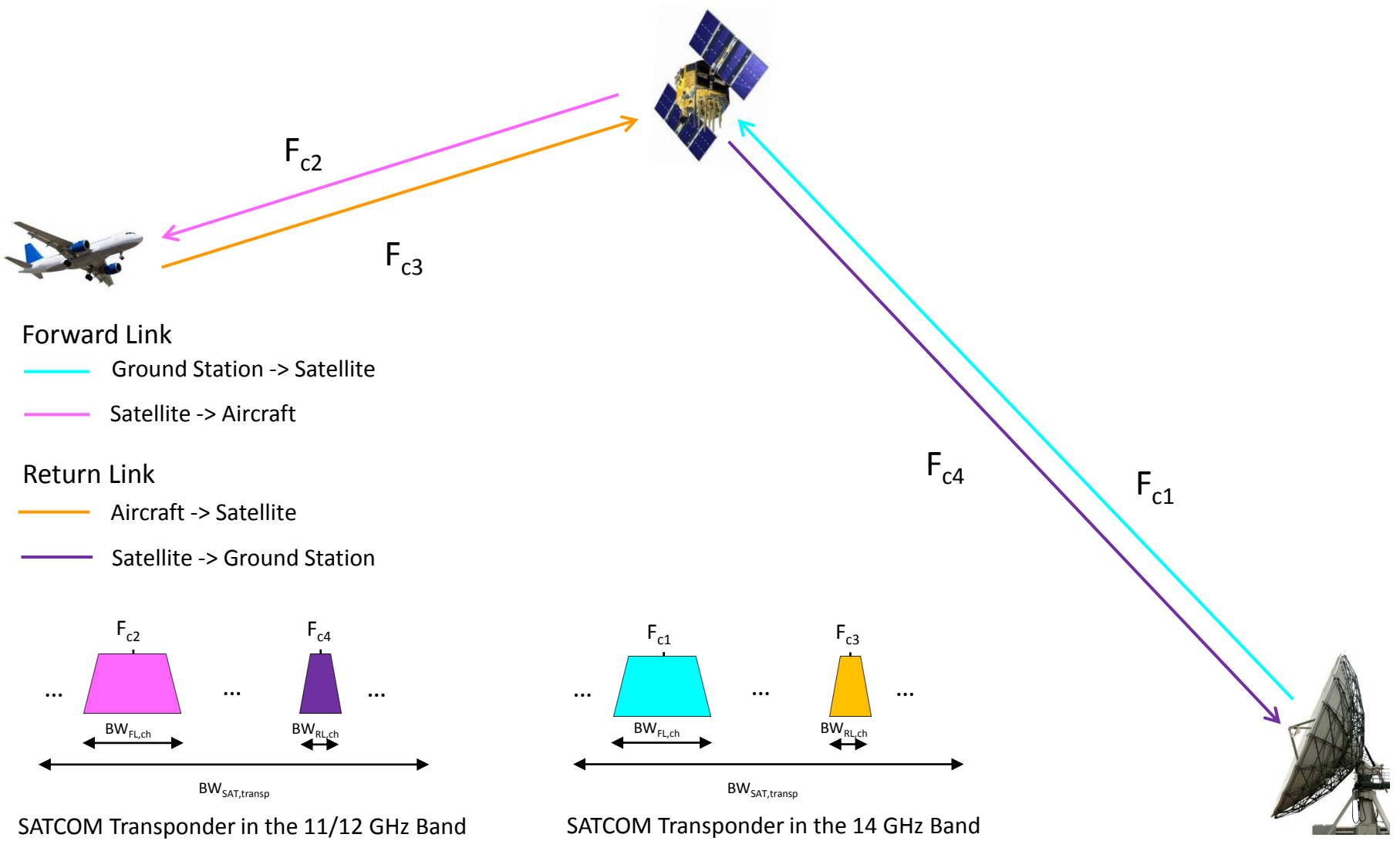
EWR Arrival Scenario "Use Case" for Analysis

- Geometry-based generic 20 mile straight in final to Rwy 22L
  - Assume 20 mile reception range for all proximate aircraft
  - Assume surface to 24,000 ft – captures over flights – consistent with prior RTCA definitions for terminal area
- Assume 20 mile reception range for all proximate aircraft
  - Consistent with ADS-B performance in high density 2025 environment
  - Consistent with satellite-based "spot beam" analysis SC-206, SG-3 is performing
  - Oval includes traffic going to nearby airports (used to develop atmospheric profiles)
- Approx 850 aircraft penetrate the oval during the 2 hr peak period
- Model coverage & resolution achieved for aircraft established on inbound track





Initial Ku-Band SATCOM Study SATCOM Links



SATCOM Transponder in the 11/12 GHz Band
(11.7-12.2 GHz Band)

SATCOM Transponder in the 14 GHz Band
(14.0-14.5 GHz Band)

Courtesy MITRE Corporation

Preliminary Findings for Ku-Band Study

- Simulation Runs
  - 0%, 30%, 50%, 80% Non Use Case loads
  - 20 random number seeds for each Use Case load
  - Total of 80 runs
- Message latencies cluster around 0.9 seconds for Non Use Case Loads up to 80%
  - Approx. 0.5 sec from slot request to slot assignment
  - Approx. 0.25 sec propagation delay for transmission of message data
- Typical Outliers
  - No data slots available for assignment – latency changes to about 2 to 9 seconds
  - Situations not handled in model
    - Slot request is lost due to bit-errors on aircraft-satellite uplink

PRELIMINARY MODEL RESULTS. VALIDATION IN PROGRESS

Courtesy MITRE Corporation

Next Steps (RTCA Activities)

- **Ordinarily proceed to development of System Performance Requirements (SPR) or Minimum Acceptable System Performance Standards (MASPS)**
- **SC-206 investigating the inclusion of Wake/ATM/MET OSED concepts in overall MASPS for Aeronautical Information Services and MET data**
- **High level RTCA discussions underway concerning scope of SC-206 (AIS & MET data link committee) and whether or not wake turbulence is included in Terms of Reference**
- **Schedule:**
  - 2nd wake conuse scenario for architecture group defined (May/June 2013)
  - Independent 1090ES study due (June/July 2013)
  - Data link architecture recommendations document release for FRAC (Sept 2013)
  - AIS/MET MASPS (slip FRAC to March 2014)
  - Revised DO-252 (Automet standards) delayed (March 2014) – due to inclusion of EDR report and possible EUROCAE re-engagement with SC-206
  - Final AIS/MET MASPS (uplink, down link, crosslink) – Approx (Sept 2014)

Questions?