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Enhancing the Distribution of Radar Surveillance Data

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- **Problem Statement**
- **Objectives**
- **Experiment Description**
- **Results**
- **Conclusions**



- **Today IP multicast is used to distribute radar surveillance data**
 - Clients are required to process all data
 - Any client can access any data stream
 - Must be within the “time to live” range of the multicast message to receive data
 - Reliable transfer not supported (required for command and control messages)
- **Middleware exists today that can meet the current distribution requirements and address the issues mentioned above**



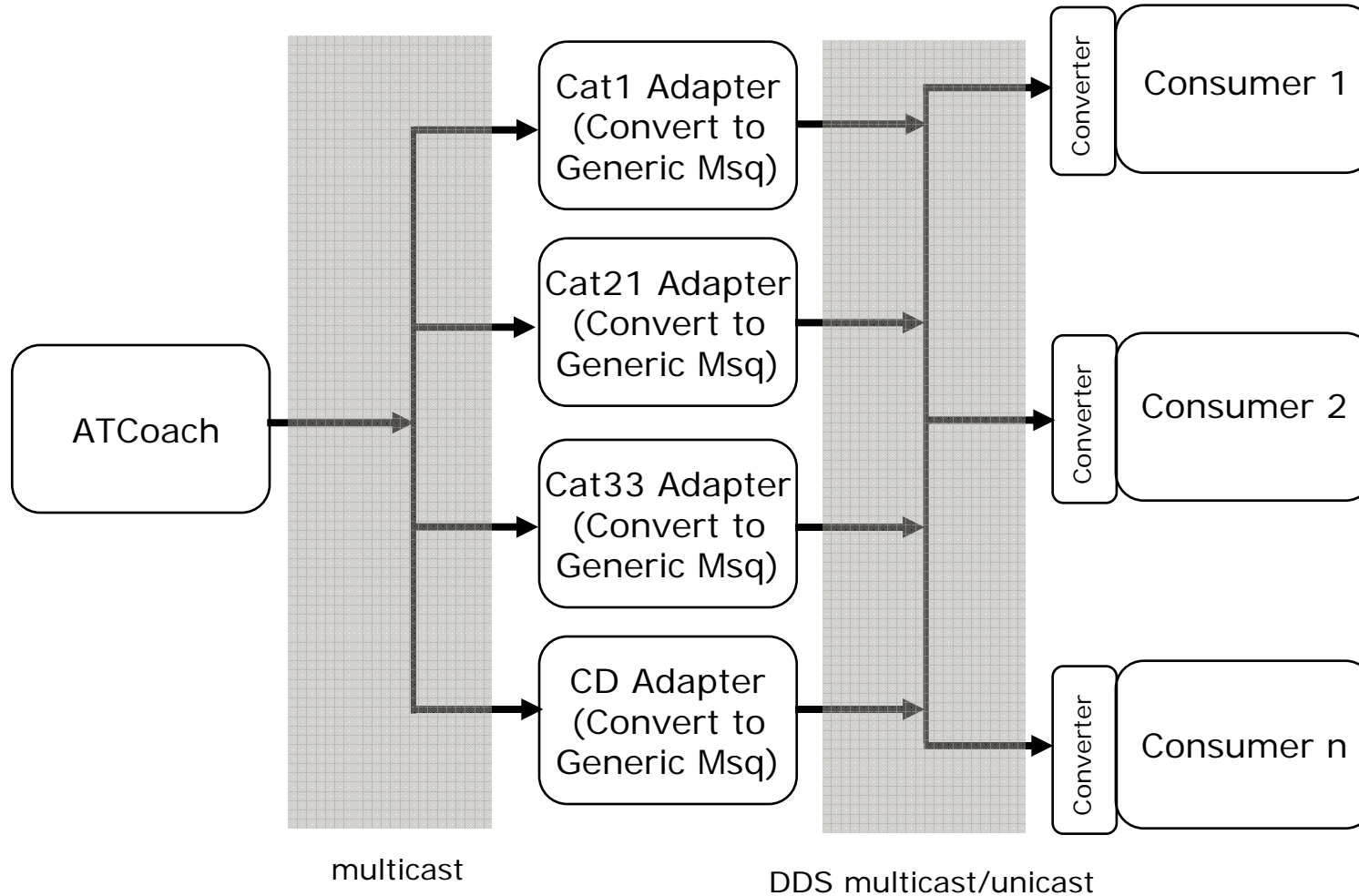
- **Subscribe to an AtCoach multicast stream and republish the data using Real Time Innovations Data Distribution Service (RTI DDS)**
- **Provide message filtering:**
 - Content
 - Time
- **Provide role based security**



Experiment Block Diagram

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- **Used to produce Asterix and Common Digitizer messages**
- **Scenarios**
 - **Vignette 1 – High Volume (used in Network Enabled Operations Spiral 0 Demonstration)**
 - **Air Route Traffic Control Center (ARTCC) models (next iteration)**
- **An ATCoach message can comprise several messages**
 - **For example, a received Common Digitizer message can contain several ASR-9, ASR-11, and CD-2 messages**



- **Adapters written for**
 - **ASTERIX Category 1 messages**
 - **ASTERIX Category 21 messages**
 - **ASTERIX Category 33 messages**
 - **Common Digitizer**
 - CD-2
 - ASR9
 - ASR11
- **Requirements**
 - **Accept data from ATCoach**
 - **Republish data using RTI DDS**



- **IDL created for each message type**
 - All elements in source message mapped to IDL
 - Message sizes quickly became unwieldy
- **Generic IDL also created**
 - Generic topic allows an application to subscribe to all message types from a single topic
 - Key fields extracted from message
 - Source Origination (i.e. Cat1), Time Stamp, Radar Id, Track Id, Position, Altitude
 - Raw source data is also included
 - Pass through for legacy systems
 - Reduces “on wire” IDL data
- **Both sequences and individual message supported**
 - When an AtCoach message is received that contains multiple messages it can either be sent as a sequence or broken out into individual messages

Sequences vs. Individual Messages



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- **Sequences do not allow for message filtering**
 - Next release of RTI DDS (4.3) eliminates the need for sequences
 - Messages are automatically batched
- **Individual messages allow filtering but increase the overhead on the wire**
 - Header required for each message
- **To reduce overheads when sending messages at a high rate, RTI DDS allows a “Pull” request for sending messages**
 - When publisher writes data it is placed in a queue
 - Subscribers periodically check to see if data is available
 - Reduces the number of required headers thus reducing the amount of data sent on the network



- **PERIODIC_BEST_EFFORT**
 - “fire and forget”
- **PERIODIC_RELIABLE**
 - Publish data with guaranteed delivery
- **BURSTY_RELIABLE**
 - Publish data with guaranteed delivery
 - Subscriber periodically ‘pings’ publisher for data (transparent to user)
 - Allows publisher to ‘batch’ messages
 - Per-Topic control of batching at Publisher write and Subscriber read supported in next RTI DDS release (4.3)

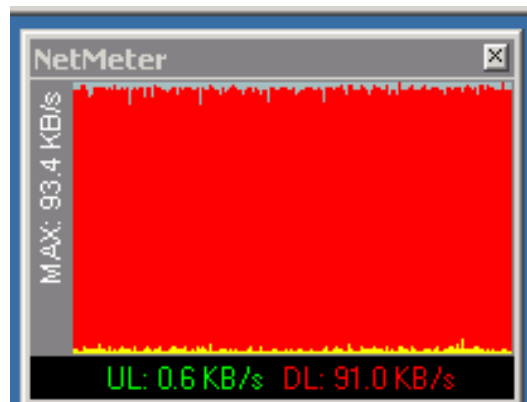
Overhead Savings using BURSTY_RELIABLE



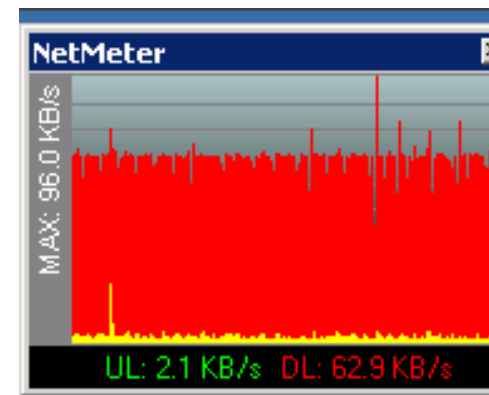
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- Test run with simulator sending 500 Cat21 msgs/sec
- Figure below shows network snapshots for **PERIODIC_BEST_EFFORT** and **BURSTY_RELIABLE**
 - **PERIODIC_BEST_EFFORT**: ~91 Kbytes/sec
 - **BURSTY_RELIABLE**: ~63 Kbytes
 - ~30% reduction in network traffic



PERIODIC_BEST_EFFORT



BURSTY_RELIABLE



- **Subscriber can set up content filtering based on any element in the data type**
- **Example:**
 - **To receive only tracks above 25,000 feet and above 45 degrees latitude the following filter can be set:**
 - “altitude > 25000 and position.lat > 45.0”
 - **If constraints are dynamic a filter parameter list can be defined**
 - “altitude > %0 and position.lat > %1”
 - Parameters can be changed in real time
- **Due to use of keys, messages are filtered on the subscriber side**



- **Subscriber can set the minimum separation between samples**
- **Samples are only updated when minimum separation has been met**
- **Example:**
 - **AtCoach sends messages at a rate of 9 msg/sec**
 - **Minimum separation not set: subscriber receive rate: 9 msg/sec**
 - **Minimum separation 1 sec: subscriber receive rate: 1 msg/sec**
 - **Minimum separation 10 sec: subscriber receive rate: 0.1 msg/sec**
- **Due to use of keys, messages are filtered on the subscriber side**

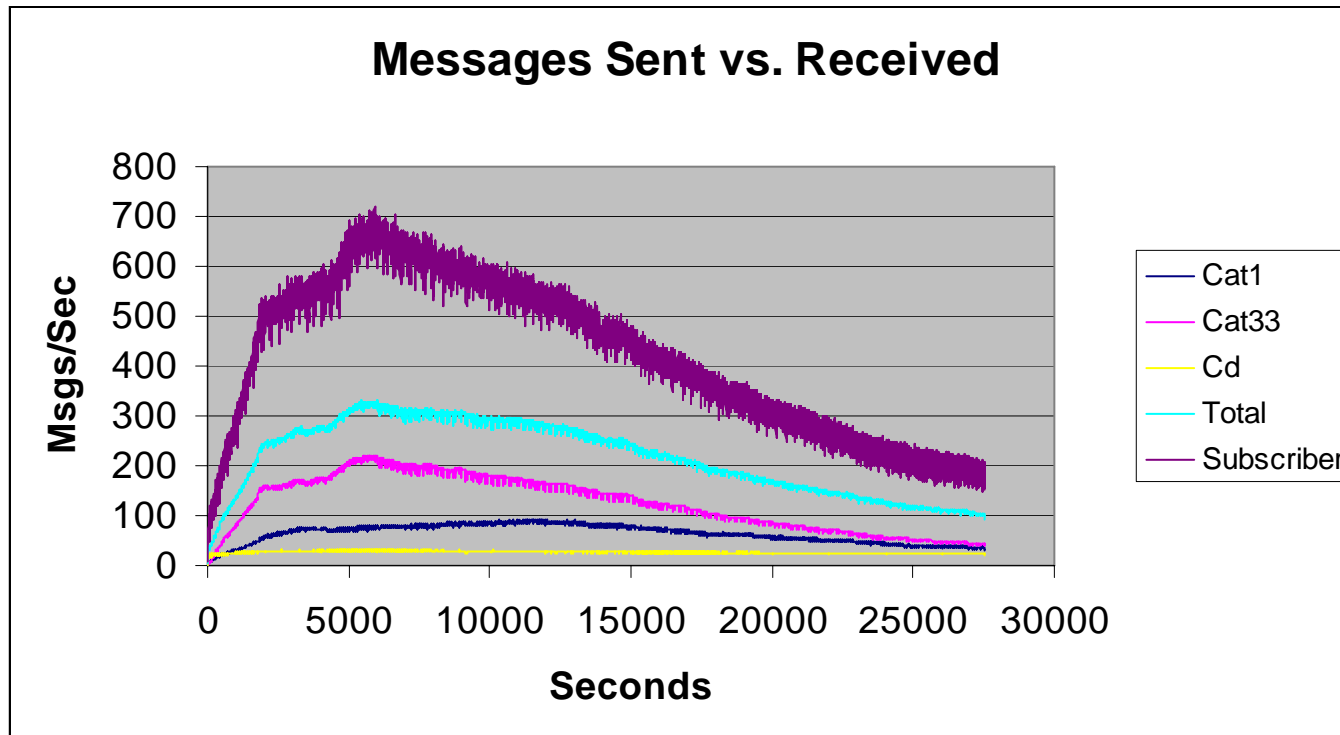
Vignette 1 - High Volume Messages (1 of 2)



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- Graph below shows message rates over time
- Publisher configured to send single messages
- Subscriber configured to receive single messages



- Cat1, Cat33 and Cd: messages received from AtCoach
- Total: sum of all messages received from AtCoach
- Subscriber: DDS messages received from Adapter

Vignette 1 - High Volume Messages (2 of 2)



- **Table below shows message statistics for the ATCoach run using the Vignette 1 high volume scenario**
 - No Cat21 messages were present
 - The 'Msgs per Msg' column shows the average number of messages present in each ATCoach message
- **Average required bandwidth: ~27 Kbytes/sec**
 - Common Digitizer: 7 Kbytes/sec
 - Cat1: 5 Kbytes/sec
 - Cat33: 15 Kbytes/sec

Message	Msg/Sec			Msg Size (bytes)			Msgs per Msg	
	Min	Max	Avg	Min	Max	Avg	Avg #	Avg Size
Common Digitizer	18	30	25	61	346	231	5.1	45
Cat1	24	94	60	33	77	47	1.3	36
Cat33	5	221	156	56	56	56	1	56



- **ATCoach messages are converted to DDS IDL messages before being sent to subscribers**
- **Size of generic IDL message**
 - **Sequence**
 - 36 bytes * (# messages) + 8 bytes + AtCoach Msg
 - **Single**
 - 36 bytes + subset of AtCoach Msg
 - **Overhead for each message**
 - 102 bytes
 - 14 Ethernet, 20 IP, 8 UDP, 60 RTPS*
- **Average required bandwidth**
 - **Sequences: ~58 Kbytes/sec (2.1 times greater than source)**
 - **Single: ~67 Kbytes/sec (2.4 times greater than source)**
- **Required bandwidth can be reduced by ‘pulling’ data from adapters (BURSTY_RELIABLE QoS)**



Per Message Overhead

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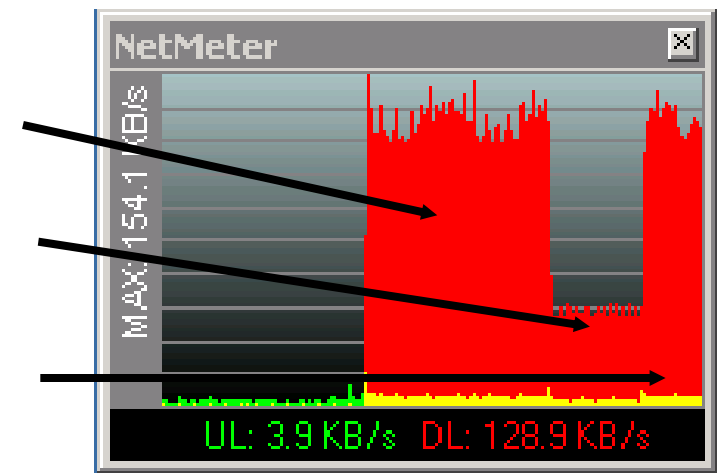
Publisher	Message	Payload (bytes)	Header (bytes)	Overhead	Msgs/Msg
AtCoach	Common Digitizer	231	42	18%	5.3
	Cat 1	47	42	89%	1.3
	Cat 33	56	42	75%	1.0
Adapters	Common Digitizer	81	102	126%	1.0
	Cat 1	72	102	141%	1.0
	Cat 33	92	102	111%	1.0



- **Current implementation consists of**
 - Three roles (Military, Commercial, Private)
 - Three levels (high, medium, low)
- **Partitions used to support role based access**
 - Ability to subdivide a topic
- **Example**
 - Publisher publishes to partitions {"Military-1", "Private-123"}
 - To receive data subscriber requires:
 - Level 1 access for military
 - Level 3 access for Private
- **Additional roles and levels can easily be added**
- **No encryption or authorization/authentication implemented at this time**



- **Figure below shows subscriber where role changes dynamically**
- **Three sources:**
 - **Adapter 1: Publishing to Groups: A,B, level Medium**
 - **Adapter 2: Publishing to Groups: A,B, level Medium**
 - **Adapter 3: Publisher to all Groups, all levels**
- **Subscriber:**
 - **Initially allowed access to all groups, level Medium**
 - **Access level changes for all groups, level Low**
 - **Access level changes for all groups, level High**





- **AtCoach**
 - **Location: Chantilly, Virginia**
 - **Host: Sun**
 - **Operating System: Solaris**
- **Adapters**
 - **Location: Chantilly, Virginia**
 - **Host: 32 bit x86**
 - **Operating System: Windows Server 2003**
- **Consumer**
 - **Location: Kent, Washington**
 - **Host: 32 bit x86**
 - **Operating System: Windows Server 2003**
- **Network: T1 link**
- **Clocks not synchronized**



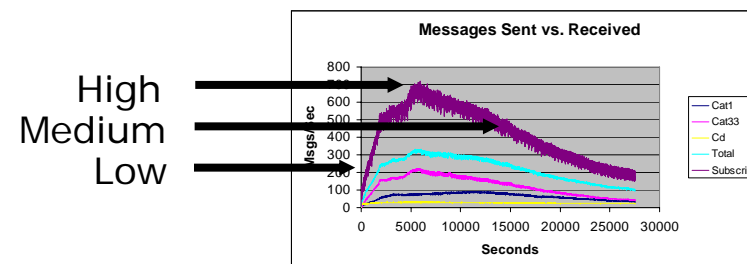
Estimated Latency: High Volume Scenario

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- **Estimated since clock were not synchronized**
 - Ping time between Chantilly and Kent ~100 ms
 - Processing time ~50 ms
 - Minimum latency: $\frac{1}{2}$ ping time + processing time = 100 ms

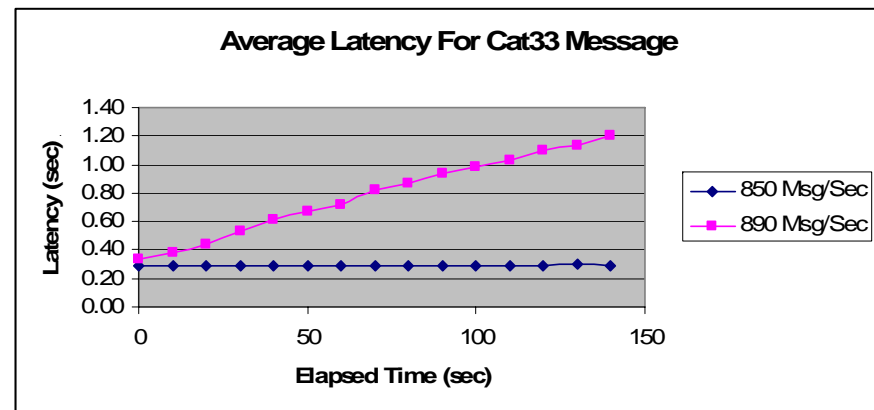
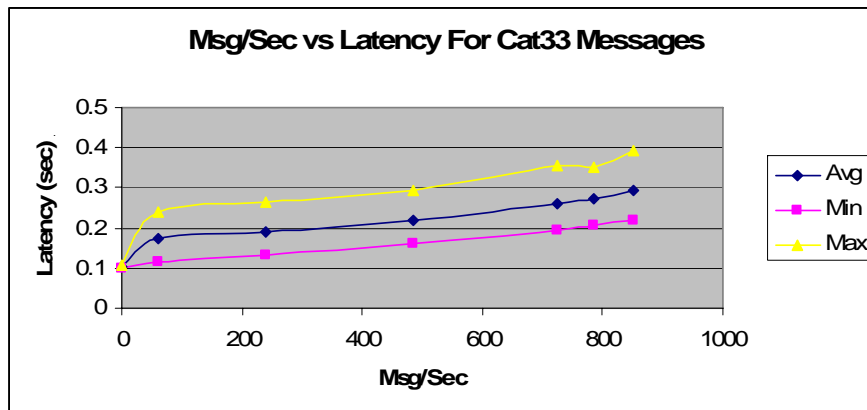
Traffic Rate	Low	Med	High
Avg (sec)	0.22	0.26	0.31
Min (sec)	0.10	0.10	0.10
Max (sec)	0.56	0.48	0.72
Msg/Sec	220	410	670





Estimated Latency: Max rate

- Increase message rate until latency grows without bound
- Constant size Cat 33 message used for test
- Maximum message rate approximately 850 msg/sec



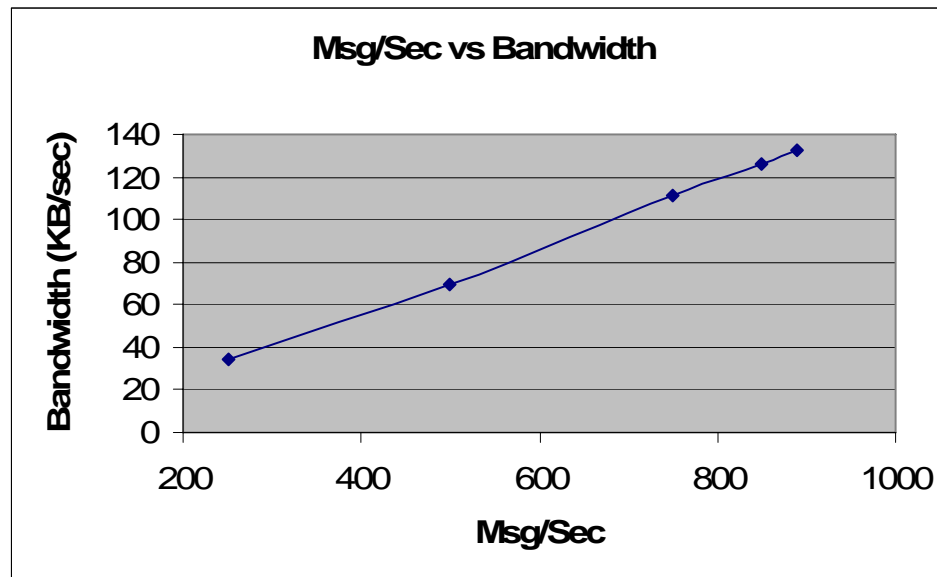
Network Bandwidth During Max Message Test



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- **Maximum message rate occurs when network bandwidth approaches 135 kilobytes/sec**





- **Able to run Vignette 1 – High Volume scenario with both sequences and single messages**
 - In NEO Spiral 0 Program, messages were sent out in batches every second
- **Next Steps**
 - Test with Air Route Traffic Control Center (ARTCC) scenarios
 - Rerun tests using next release of RTI DDS 4.3 (mid May)
 - Performs batching transparent to user
 - Allows filtering with batching

Backup Slides



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- **AtCoach**
 - **Peak required bandwidth: ~42 Kbytes/sec**
 - Common Digitizer: 12 Kbytes/sec
 - Cat1: 9 Kbytes/sec
 - Cat33: 21 Kbytes/sec
- **DDS**
 - **Sequences: ~92 Kbytes/sec (2.2 times greater than source)**
 - **Single: ~114 Kbytes/sec (2.7 times greater than source)**



Common Digitizer-2 (CD-2) Message

- **AtCoach sends each 13 bit word as a 2 byte word with the upper three bits set to 0**

Table 3-IX. Serial Interface Design Characteristics Table

Message Flow	Message Name	Estimated Message Frequency	Message Size (bits)	Maximum Transfer Time Constraints *
From En Route Surveillance System	Idle Word	Variable*	13	0.3 seconds
	Beacon	Variable*	91	
	Beacon RTQC	1/scan	91	
	Beacon Strobe	Variable*	52	
	Search	Variable*	52	
	Search RTQC	1/scan	52	
	Search Strobe	Variable*	52	
	Weather Map	Variable*	52	
	Status	1/scan**	52	
	Radar Data Verifier	1/scan***	52	

Variable to the maximum number of the target reports per radar. See Table 3-X.

* Variable to the maximum number of target reports per radar

** Once per scan and whenever a change in status occurs

*** Once per scan for each channel

Table 3-X. Peak Target Report Rates for Long Range Surveillance Sources

Parameter	Number of Target Reports	Interval
Scan (360°) Peak	998	12 seconds
Large Sector (90°) Peak	400	3 seconds
Small Sector (3.6°) Peak	60	120 milliseconds
Azimuth Sector (2.25°) Peak	60	75 milliseconds



- **AtCoach sends each 13 bit word as a 2 byte word with the upper three bits set to 0**

Table 3-IV. Interface Requirements

Message Flow	Message Name	Estimated Message Frequency	Message Size (bits)	Maximum Transfer Time Constraints
From ASR to ECG	Idle Message	during idle time and at least once between successive messages **	13	0.3 seconds
	Beacon Message	as necessary **	91	
	Beacon RTQC	1/scan	91	
	Search Message	as necessary **	52	
	Search RTQC	1/scan	52	
	Sector Mark	32/scan	52	
	Weather Message	as necessary **	416	
Status Message	1/scan (*)	52		

* Once per scan and whenever a change in status occurs.

** Variable to the maximum number of the target reports per radar. See Table 3-V.

Table 3-V. Peak Target Report Rates for Short-Range Surveillance Sources

Parameter	Number of Target Reports	Interval
Scan (360°) Peak	1100	4.8 seconds
Large Sector (90°) Peak	250	1.2 seconds
Medium Sector (22.5°) Peak	100	300 milliseconds
Small Sector (2.625°) Peak	32	35 milliseconds

Source: Common Digitizer Airport Surveillance Radar (CD-ASR), Aug 31, 2001



Category 1 Message

- Message may contain any of the fields below

The following UAP shown in Table 3 shall be used for the transmission of Primary, SSR or combined Primary/SSR tracks:

Table 3 - Standard UAP for Track Information

FRN	Data Item	Information	Length in Octets
1	I001/010	Data Source Identifier	2
2	I001/020	Target Report Descriptor	1+
3	I001/161	Track/Plot Number	2
4	I001/040	Measured Position in Polar Coordinates	4
5	I001/042	Calculated Position in Cartesian Coordinates	4
6	I001/200	Calculated Track Velocity in polar Coordinates	4
7	I001/070	Mode-3/A Code in Octal Representation	2
FX	-	Field Extension Indicator	-
8	I001/090	Mode-C Code in Binary Representation	2
9	I001/141	Truncated Time of Day	2
10	I001/130	Radar Plot Characteristics	1+
11	I001/131	Received Power	1
12	I001/120	Measured Radial Doppler Speed	1
13	I001/170	Track Status	1+
14	I001/210	Track Quality	1+
FX	-	Field Extension Indicator	-
15	I001/050	Mode-2 Code in Octal Representation	2
16	I001/080	Mode-3/A Code Confidence Indicator	2
17	I001/100	Mode-C Code and Code Confidence Indicator	4
18	I001/060	Mode-2 Code Confidence Indicator	2
19	I001/030	Warning/Error Conditions	1+
20	-	Reserved for Special Purpose Indicator (SP)	-
21	-	Reserved for RFS Indicator (RS-bit)	-
FX	-	Field Extension Indicator	-
22	I001/150	Presence of X-Pulse	1

where:

- the first column indicates the FRN associated to each Data Item used in the UAP;
- the fourth column gives the format and the length of each item. A stand-alone figure indicates the octet count of a fixed-length Data Item, 1+ indicates a variable-length Data Item comprising a first part of one-octet followed by n-octets extents as necessary.



Category 33 Message

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- Message may contain any of the fields below

Table A-1. Cat 033 (V 1) User Application Profile and Construction

FRN	Data Item	Length in Bytes (when present)
1	Version Number	1
2	Data Source Identifier	2
3	Link Technology Indicator	1
4	Time of Applicability	3
5	Target Address	4
6	Integrity and Accuracy Parameters	2
7	Latitude/Longitude	6
8	Pressure Altitude	2
9	Velocity (Airborne)	5
10	Velocity (Surface)	3
11	Mode 3/A Code	2
12	Target Identification	6
13	Emitter Category	1
14	Target Status	1
15	Geometric Altitude	2
16	<i>Reserved for Future Definition</i>	N/A
17	Time of Message Transmission	4
18	Time of Message Reception	4
19	<i>Reserved for Future Definition</i>	N/A
20	<i>Reserved for Future Definition</i>	N/A
21	<i>Reserved for Future Definition</i>	N/A
22	<i>Reserved for Future Definition</i>	N/A