Spectrum Demand for Air/Ground Air Traffic Management Communications

May 5-7, 2008

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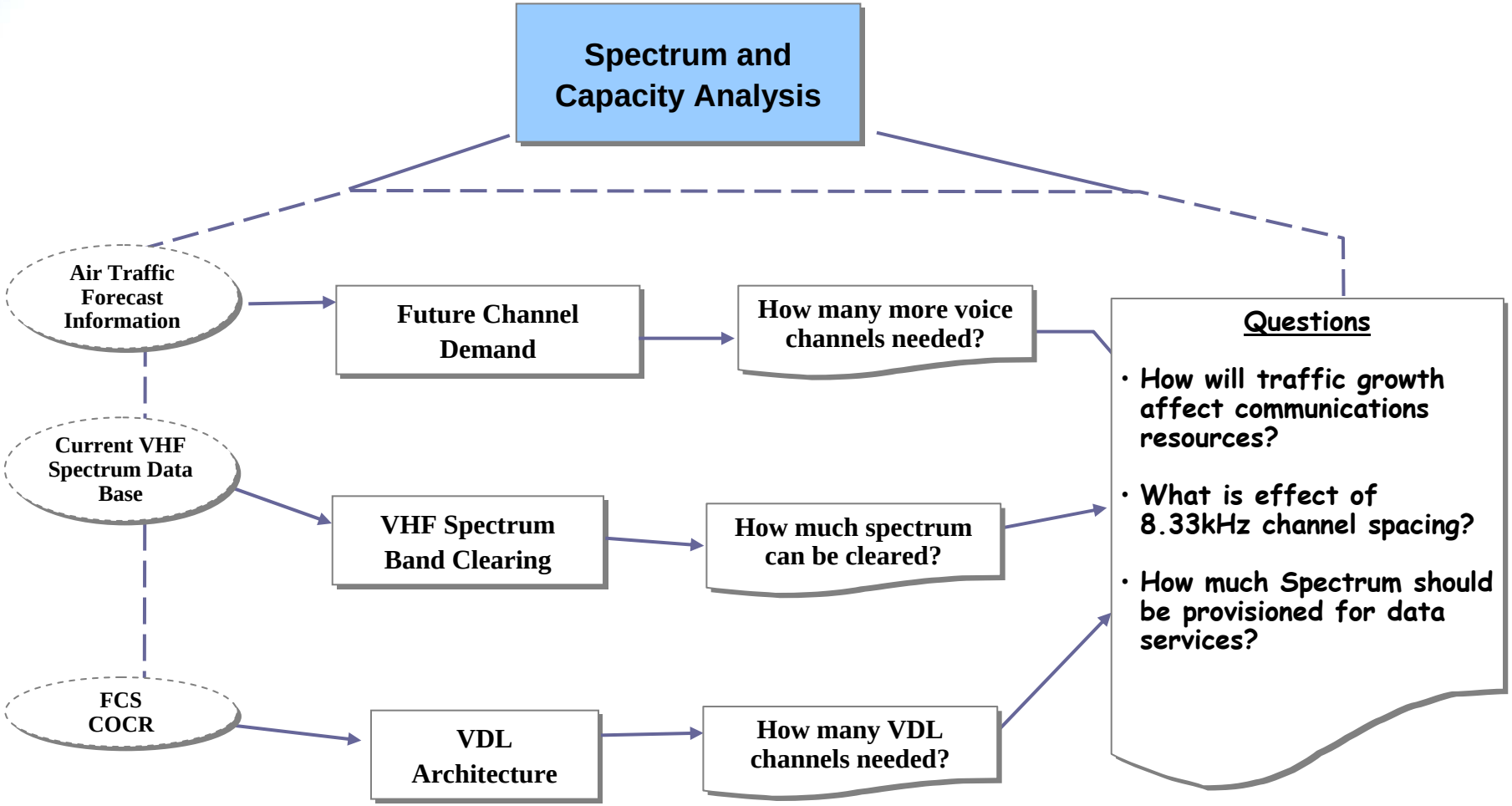
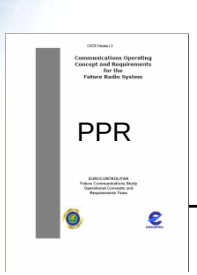
Introduction



Data Communications Assessment



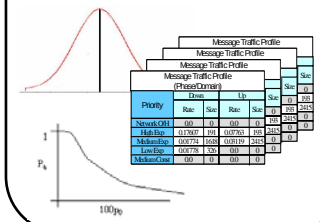
ETMS data

Existing Siting

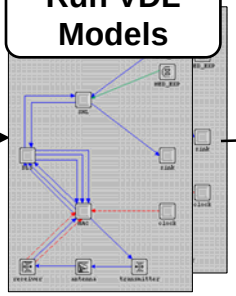
Define Supported Applications

Application	Profile		
ATC			
• Controller/Flight Crew	X	X	X
• ADAP	X	X	X
• FIS	X		X
• TIS and Surveillance	X		
• Emerg and Anc	X	X	X
• Comm Mgmt	X	X	X
AOC			
• OOOI	X	X	
• Graphical Weather	X		
• Fuel Status	X	X	
• NOTAM	X	X	
• Update Electronic Library	X		

Develop Message Traffic Input Model

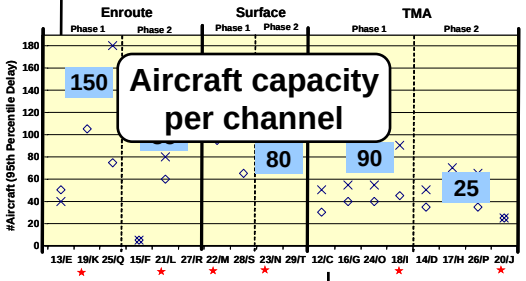


Run VDL Models



Consider effects of:
- "Hidden Terminal"
- Co-site interference

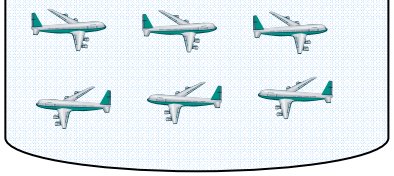
Frequency Planning



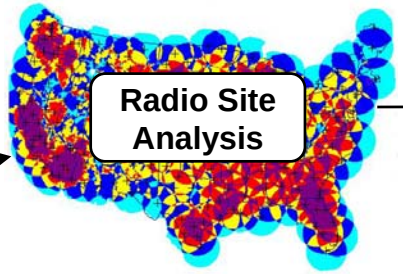
Aircraft capacity per channel

Number of VDL channels required

Number of equipped aircraft in airspace



Radio Site Analysis



Determine Number of Radios and Sites

Application By Segment

Year	2017	2022	2027
Equipage	14-54%	22-71%	29-86%
Application	Segment 1	Segment 2	Segment 3
ATC Clearance Service (ACL)	X	X	X
ATC Microphone Check (AMC)	Free-Text	X	X
Common Trajectory Coordination Service (COTRAC)			
(Initial 4D in Mixed Airspace)	X[1]	X[2]	X
(4D in Perf-based Airspace)		X[2]	X
(Widespread 4D down to Paired App)			X
Data Link Logon Service (DLL)	X	X	X
ATC Communications Management Service (ACM)			
TOCIC	X	X	X
NDA	X	X	X
Data Link Automatic Terminal Information Service (D-ATIS)	X	X	X
Data Link Taxi Service (D-TAXI)			
Departure	Coded	X	X
Arrival		X	X
Departure Clearance Service (DCL)	X	X	X
Arrival Manager Information Delivery Service (ARMAND)	P	X	X
Beacon Code	X	X	X
Expect Departure Clearance Time (EDCT)	Free-Text	Free-Text	Free-Text
Tailored Arrival Procedure (TAP)/ Continuous Descent Arrival (CDA)	X	X	X
Pilot Preference Downlink (PPD)		X	X
Flight Path Intent Service (FLIPINT) (aka ADS-C)		X	X
Data Link Flight Plan Update Service (D-FLUP)		X	X
Data Link Surface Information Guidance (D-SIG)			
Uplink of Static Airport Map		X	
Augmented Surface Map Update			X
M&S, C&P, ITP			X

1. Complex ACL msg used
2. COTRAC Msg size decreased for simpler trajectories

Frequency / Sites / Transceivers ATS&AOC (with DEFLATE) – High User Response

		# Frequencies			# Sites			# Transceivers			
		Enroute	TMA	Surface	Enroute	TMA	Surface	Enroute	TMA	Surface	CSCs
2014	**Seg 1**	12	0	0	142	0	56	~ 142	0	56	198
2018	**Seg 1**	12	0	3	142	0	126	~ 142	0	126	268
2022	**Seg 2**	24	10	3	242	106	196	~ 407	124	196	438
2027	**Seg 2**	36	10	6	242	106	196	~ 528	132	264	438
2027	**Seg 3**	36	14	6	242	106	396	~ 649	162	466	638

Total Subband: Seg 1: **~ 0.33 MHz**
Seg 2: **~ 1.02 MHz**
Seg 3: **~1.54 MHz**
Assuming no overlap in frequencies between domains

Initial results show 744 sites, although likely to be able to share between domains 638 sites, if you assume TMA transceivers are cosited with Airport transceivers

- **Assumes ATS+AOC traffic on the same channels**
- **Assumes subbanding and 115 nmi enroute service volumes**
- **Subband includes 10% channel margin <u>but not 25/100kHz guard band(s)</u>**
- **220 Enroute sites based on terrain modeling study**
- **# of Enroute transceivers assumes full frequencies at 50/50/75% sites, for Seg 1/2/3 respectively. Others have single frequency**
- **There are unutilized frequencies within the reuse pattern that may be usable in other domains**
- **Does not account for possible frequency needs associated with multiple service providers**

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Frequency / Sites / Transceivers ATS Only (with DEFLATE) – High User Response

		# Frequencies			# Sites			# Transceivers			
		Enroute	TMA	Surface	Enroute	TMA	Surface	Enroute	TMA	Surface	CSCs
2014	**Seg 1**	12	0	0	142	0	56	~ 142	0	56	198
2018	**Seg 1**	12	0	3	142	0	126	~ 142	0	126	268
2022	**Seg 2**	24	9	3	242	106	196	~ 407	106	196	438
2027	**Seg 2**	24	10	3	242	106	196	~ 407	116	196	438
2027	**Seg 3**	24	14	6	242	106	396	~ 468	150	466	638

Total Subband: Seg 1: **~ 0.33 MHz**
Seg 2: **~ 0.99 MHz**
Seg 3: **~1.21 MHz**
Assuming no overlap in frequencies between domains

Initial results show 744 sites, although likely to be able to share between domains 638 sites, if you assume TMA transceivers are cosited with Airport transceivers

- **Assumes ATS and AOC traffic on DIFFERENT channels**
- **Assumes subbanding and 115 nmi enroute service volumes**
- **Subband includes 10% channel margin but not 25/100kHz guard band(s)**
- **220 Enroute sites based on terrain modeling study**
- **# of Enroute transceivers assumes full frequencies at 50/50/75% sites, for Seg 1/2/3 respectively. Others have single frequency**
- **There are unutilized frequencies within the reuse pattern that may be usable in other domains**
- **Does not account for possible frequency needs associated with multiple service providers**

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Impact of Payload Compression

- **For High User Response:**

ATS + AOC

	No Compression	With Compression
Segment 1	0.33 MHz	0.33 MHz
Segment 2	1.35 MHz	1.02 MHz
Segment 3	2.39 MHz	1.54 MHz

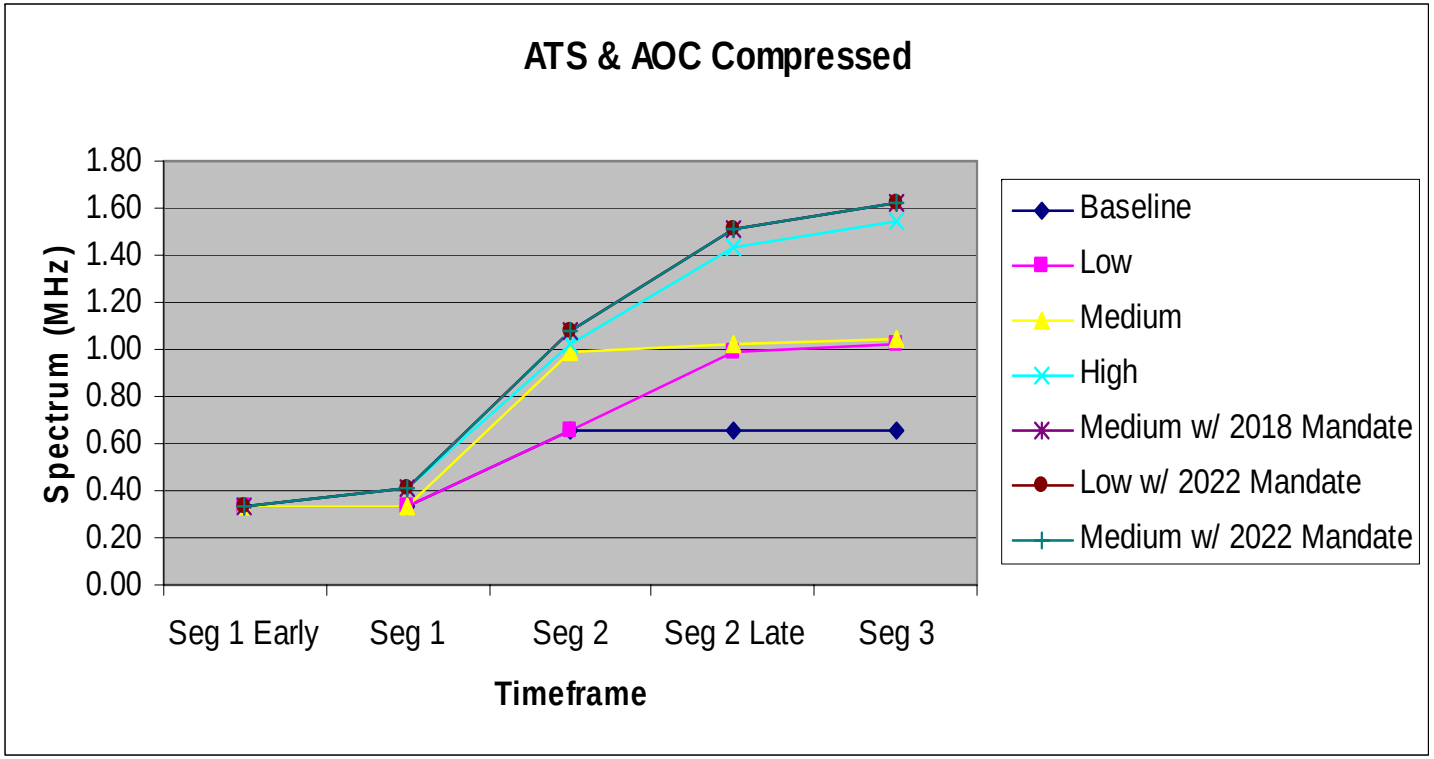
ATS Only

	No Compression	With Compression
Segment 1	0.33 MHz	0.33 MHz
Segment 2	1.02 MHz	0.99 MHz
Segment 3	1.90 MHz	1.21 MHz

- **DEFLATE provides ~36% spectrum savings in Seg 3 timeframe**
- **Standardized, but not currently implemented**

Frequency Demand

- **Frequency Demand strongly dependent on user equipage response & use of payload compression**



Impact of Mixed ATN/AOA Networking

		# Frequencies			# Sites			# Transceivers			
		Enroute	TMA	Surface	Enroute	TMA	Surface	Enroute	TMA	Surface	CSCs
2014	**Seg 1**	12	0	0	142	0	56	~ 142	0	56	198
2018	**Seg 1**	24	0	3	142	0	126	~ 213	0	126	268
2022	**Seg 2**	36	10	3	242	106	196	~ 528	130	196	438
2027	**Seg 2**	48	14	6	242	106	196	~ 649	150	264	438
2027	**Seg 3**	84	21	6	242	106	396	~ 1375	234	466	638

Mixed ATN & AOC

Total Subband: Seg 1: **~ 0.33 MHz**
Seg 2: **~ 1.35 MHz**
Seg 3: **~3.05 MHz**
Assuming no overlap in frequencies between domains

ATN Only

Total Subband: Seg 1: **~ 0.33 MHz**
Seg 2: **~ 1.02 MHz**
Seg 3: **~1.54 MHz**
Assuming no overlap in frequencies between domains

Equipage Rates Over Time and User Interest

Equipage Response Profile	2014	2018	2022	2027
Baseline	8%	14%	22%	29%
Low	12%	22%	32%	41%
Medium	17%	35%	48%	59%
High	25%	54%	70%	85%

Percentage of Equipped Aircraft using AOA

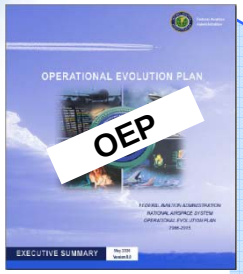
Year	Equipage Response Profile		
	Low	Medium	High
2014	56%	N/A	44%
2018	N/A	34%	27%
2022	N/A	N/A	20%
2027	N/A	N/A	16%

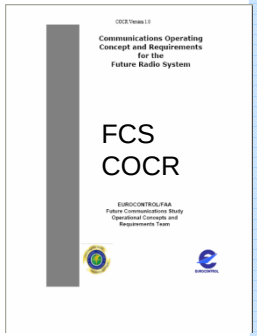
Need for 8.33 kHz Voice

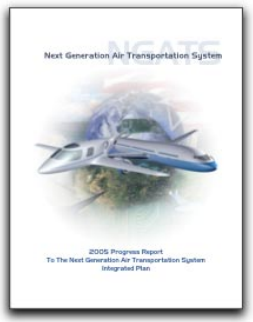
- **Repacking existing voice frequencies can clear about 1MHz and about 300-400kHz of 136-136.475 is available**
- **Conversion to 8.33kHz from FL240+ can yield up to about 2.2MHz (+ ~400kHz)**

- **In a mixed ATN/AOA environment, 8.33 kHz voice will probably be needed sometime between 2022 and 2027, depending on continuing need for voice channels**
  - **Variability depending on assumptions for**
    - **voice frequency demand**
    - **aircraft equipage**
    - **aircraft density**
    - **desired applications**
    - **Segregated ATS/AOC networks or Availability of AOC spectrum for joint ATS/AOC networks**
  - **Unclear how data comm will affect voice frequency demand in the future**
  - **Payload compression SIGNIFICANTLY reduces the spectral footprint of Data Communications**

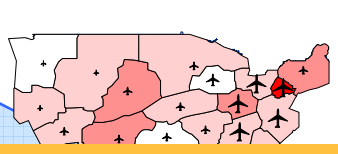
Summary



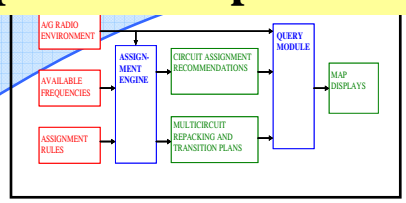




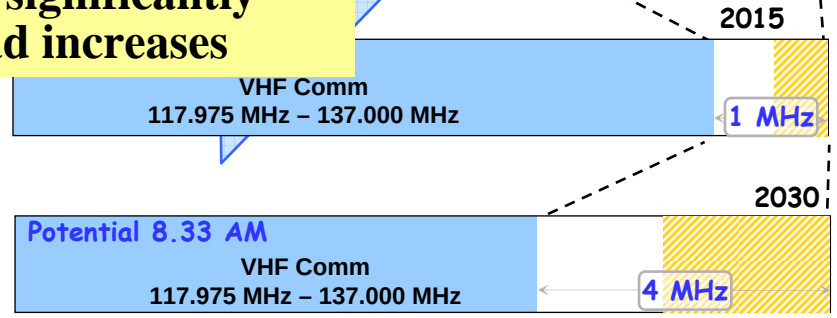
Future Demand Assessment



- **Segment 1 should be supportable keeping 25kHz voice channels**
- **Segments 2 & 3 likely require some voice channels to adopt 8.33 KHz channelization to free sufficient spectrum due to mixed ATN/AOA equipage**
- **Use of DEFLATE compression significantly reduces spectrum impact as load increases**



ojected Spectrum availability and VDL Needs through NextGen time frame



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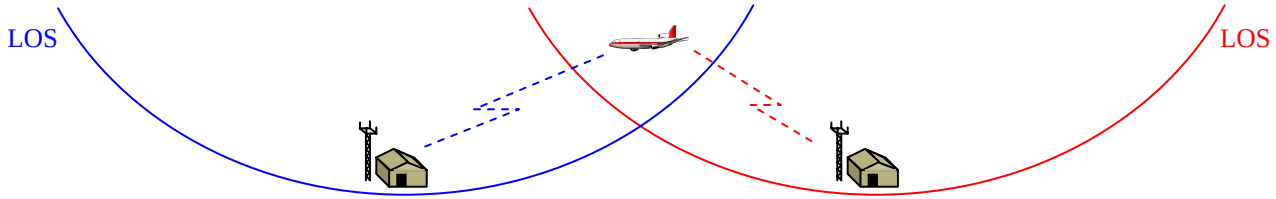
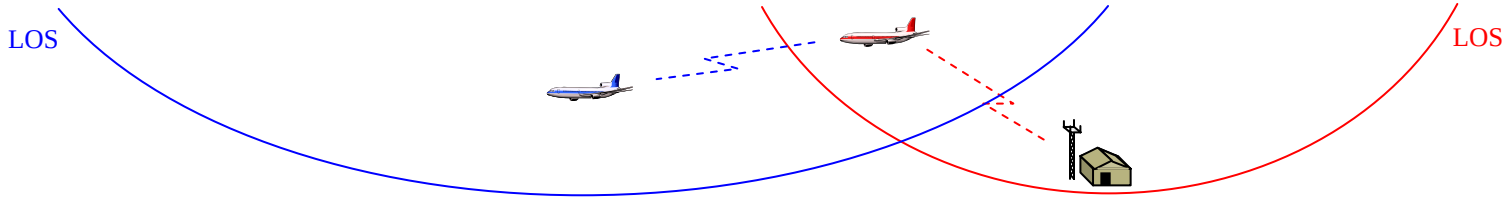
Backup

Hidden Transmitter Interference

- **Ground Station – Ground Station Interference**
  - **Two ground stations that do not have line of sight with each other have overlapping transmissions. Any aircraft that has line of sight to both ground stations will not receive either transmission**



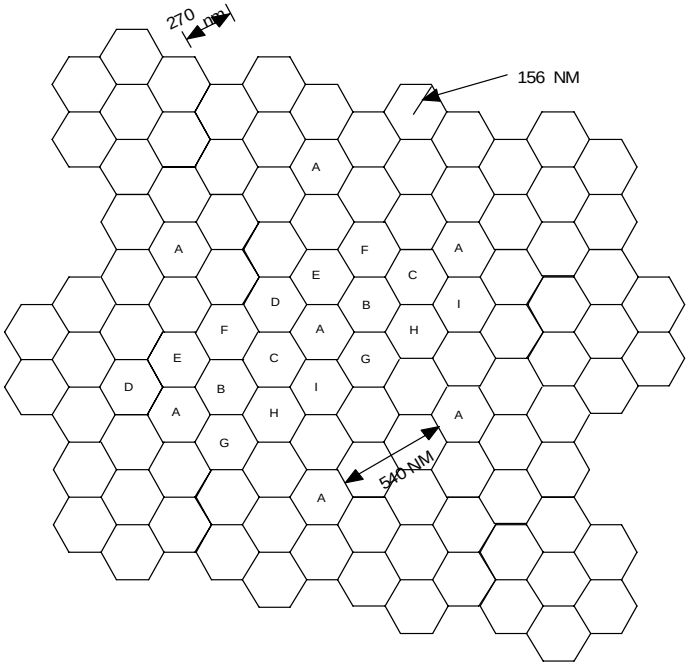
- **Ground Station – Aircraft Interference**
  - **A ground station and an aircraft that do not have line of sight with each other have overlapping transmissions. Any aircraft that has line of sight to both the aircraft and the ground station will not receive either transmission.**

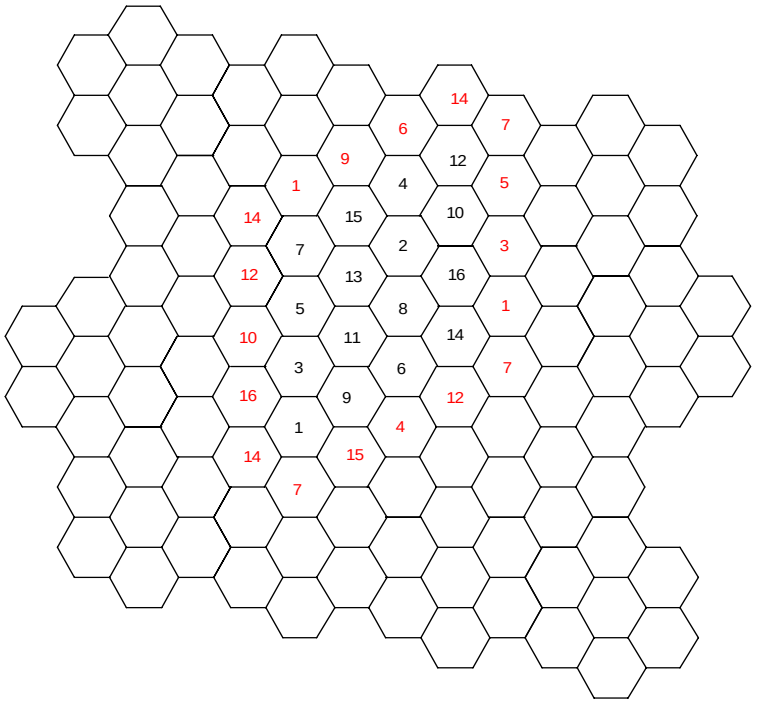


- **Both hidden transmitter cases only affect uplink transmissions**

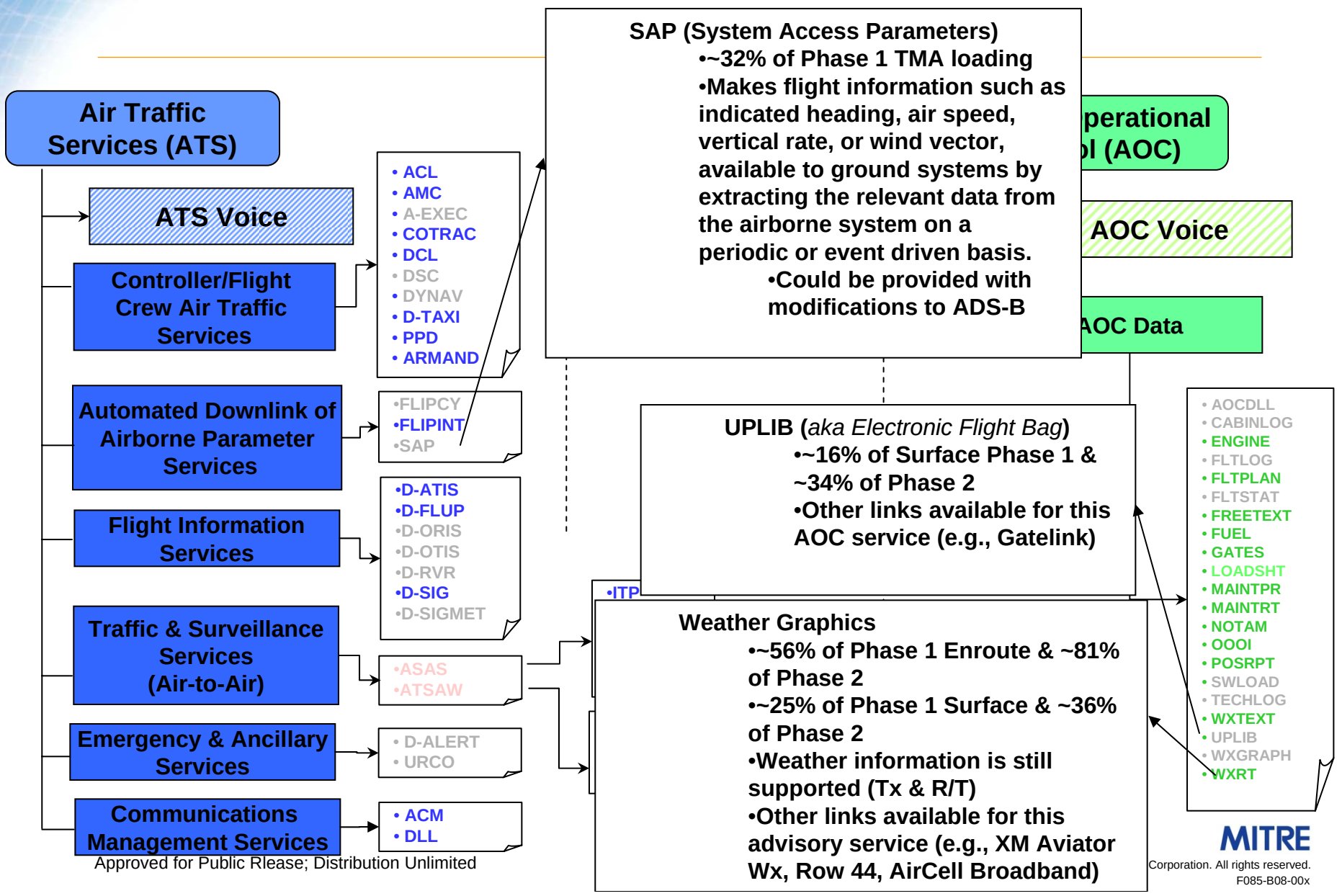
Concepts for Frequency Layout

- **9- and 16-Frequency reuse pattern**





PPR-Filtered COCR-Defined Services



Traffic Load by Segment (Input for Simulations)

		Airport						TMA						Enroute					
		Segment 1		Segment 2		Segment 3		Segment 1		Segment 2		Segment 3		Segment 1		Segment 2		Segment 3	
Type	Priority	Arrival Rate	Avg Size	Arrival Rate	Avg Size	Arrival Rate	Avg Size	Arrival Rate	Avg Size	Arrival Rate	Avg Size	Arrival Rate	Avg Size	Arrival Rate	Avg Size	Arrival Rate	Avg Size	Arrival Rate	Avg Size
Uplink	Network O/H	0.0014852	911	0.0014852	911	0.0017229	924	0.0037924	747	0.0037924	747	0.0046078	748	0.003889	794	0.003889	794	0.002995	813
Uplink	High Exp	0.0061798	1756	0.0073425	891	0.0087952	1377	3.083E-07	856	0.0373746	763	0.0464552	1417	0.006723	2234	0.008204	802	0.006037	4782
Uplink	Medium Exp	0.0002846	808	0.0020461	3681	0.002491	3929	0.0020637	800	0.0097166	3227	0.0112756	3412	0.000417	1084	0.003194	1044	0.002571	924
Uplink	Low Exp	0.004336	3402	0.004607	5120	0.0055556	10913	0.0039088	2695	0.0039088	2695	0.0066383	2170	0.009815	2420	0.009815	2420	0.009627	3489
Downlink	Network O/H	0.0013497	736	0.0013497	736	0.0015436	745	0.002174	559	0.002174	559	0.0025817	549	0.002407	659	0.002407	659	0.001978	707
Downlink	High Exp	0.0061795	1538	0.0073423	908	0.0088308	1330	0	0	0.1373743	832	0.0667126	1190	0.006722	1943	0.038204	831	0.01224	2506
Downlink	Medium Exp	0.0001897	768	0.0015447	2077	0.0018996	2176	0.0012382	744	0.0083015	2573	0.0100956	2627	0.000287	731	0.003065	3718	0.00251	4743
Downlink	Low Exp	0.0121006	991	0.0121006	991	0.0142594	1005	0.0254307	1257	0.0254307	1257	0.0293833	1619	0.017796	1063	0.017796	1063	0.016037	1173
TD95 (s)	Network O/H	3.8		3.8		1.4		3.8		3.8		1.4		3.8		3.8		1.4	
TD95 (s)	High Exp	3.8		3.8		1.4		3.8		3.8		1.4		3.8		3.8		1.4	
TD95 (s)	Medium Exp	9.2		9.2		2.4		9.2		9.2		2.4		9.2		9.2		2.4	
TD95 (s)	Low Exp	13.6		13.6		13.6		13.6		13.6		13.6		13.6		13.6		13.6	
Uplink	Bps/ac	27		39		84		15		73		122		42		37		67	
Downlink	Bps/ac	23		23		31		34		169		155		34		64		63	
Up & Down	Bps/ac	50		62		115		49		242		277		76		101		130	

- **Message rate Poisson distribution**
- **Message size Exponential distribution**