「國際航空CNS/ATM基礎建設之發展趨勢及我國建置策略之研究」
期末簡報

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簡報內容

- 計劃內容

- 期末報告簡報

計 畫 目 標

- 研究我國航空交通在**CNS/ATM**新技術及標準的衝擊下，其系統架構及營運模式所會發生之演進。
- 了解國際**CNS/ATM**相關研究及測試計畫所遇到之技術瓶頸、營運障礙及其解決方法。
- 依據我國成為亞太空運中心之政策目標，擬定**CNS/ATM**環境下航空交通基礎建設之發展藍圖及建置策略。

研究內容及工作項目

- 研究內容 ：
  - 關鍵技術研究
  - 系統架構/功能研究
  - 作業需求研究
  - 發展計畫及活動研究
  - 建置策略研究

- 工作項目 ：
  - 完成「國際航空交通CNS/ATM基礎建設趨勢分析報告」
  - 完成「我國航空交通基礎建設建置策略研究報告」

工作時程

工作項目 / 工作進度 / 月份	90/10	90/11	90/12	91/01	91/02	91/03	91/04	91/05	91/06	91/07	91/08	91/09
(1)國際航空CNS/ATM基礎建設趨勢分析報告				M1								
(2)我國航空交通基礎建設建置策略研究報告								M2				
進度百分比(%)	50%				100%							

查核點M1：(期中報告)國際航空CNS/ATM基礎建設趨勢分析報告

查核點M2：(期末報告)我國航空交通基礎建設建置策略研究報告

執行狀況

1. **91/02/08** 提交期中報告初稿
2. **91/03/11**舉行期中簡報
3. **91/06/10** 提交期末報告初稿
4. **91/07/09** 舉行期末簡報
5. 每個月舉行工作會議彙報、研討專案相關議題
6. 多次與民航局、航太產業、航空公司相關人員研討**CNS/ATM**技術趨勢及建置策略

具體成果

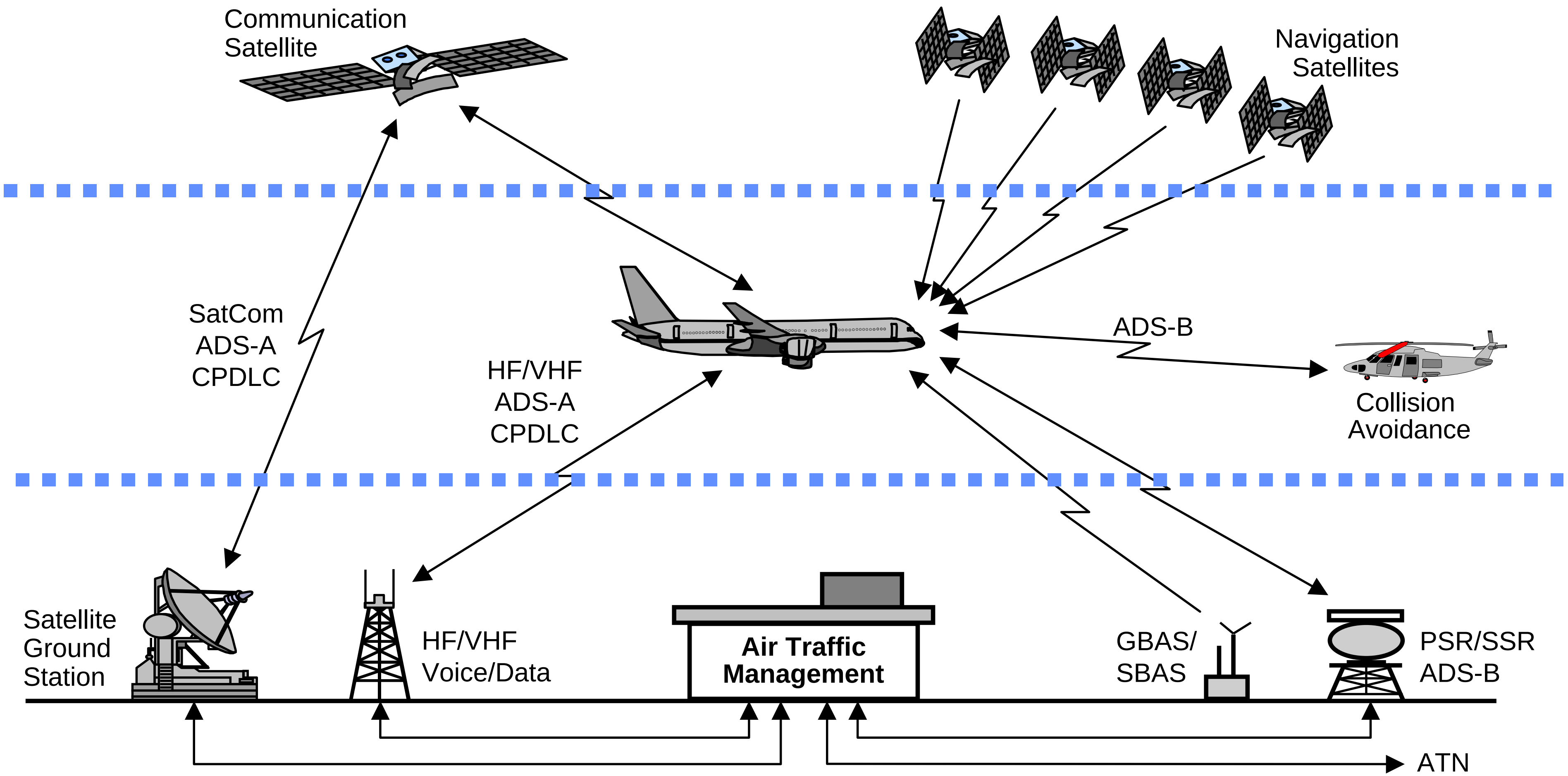
1.國際航空CNS/ATM基礎建設趨勢分析報告：

- 通訊 (Communications)：航管作業及航空公司之資料鏈路通訊作業需求、航空電訊網路(ATN)之架構分析等
- 導航 (Navigation)：現有衛星導航系統之規格比較、航空導航之作業需求標準等
- 監視 (Surveillance)：未來監視系統之作業架構及功能規格、雷達/自動回報監視融合處理作業原理等
- 航空交通管理 (Air Traffic Management)：空中碰撞預警、地障碰撞預警、空域監視及管理等

2.我國航空交通基礎建設建置策略研究報告：

- 我國航空通訊基礎建設建置策略研究
- 我國航空導航基礎建設建置策略研究
- 我國航空監視基礎建設建置策略研究
- 我國航空航空交通管理建置策略研究

CNS/ATM 航管環境



CNS:
- 資料鏈路通訊 (Data Link)
- 衛星導航 (GNSS)
- 自動回報監視 (ADS)
- 管制員/駕駛員資料鏈路通訊 (CPDLC)

ATM:
- 空域管理 (ASM)
- 流量管理 (ATFM)
- 先期碰撞預警 (Conflict Probe)
- 合作協調決策 (CDM)

CNS/ATM 的技術變革

- 通訊 [Communications]：語音 ⇒ 數位/語音通訊

  涵蓋全球、即時、高效率、及正確可靠之數位資料/語音通訊

- 導航 [Navigation]：地面 ⇒ 衛星導航

  單一航電設備，可進行越洋、航路、到精確進場之高精度導航

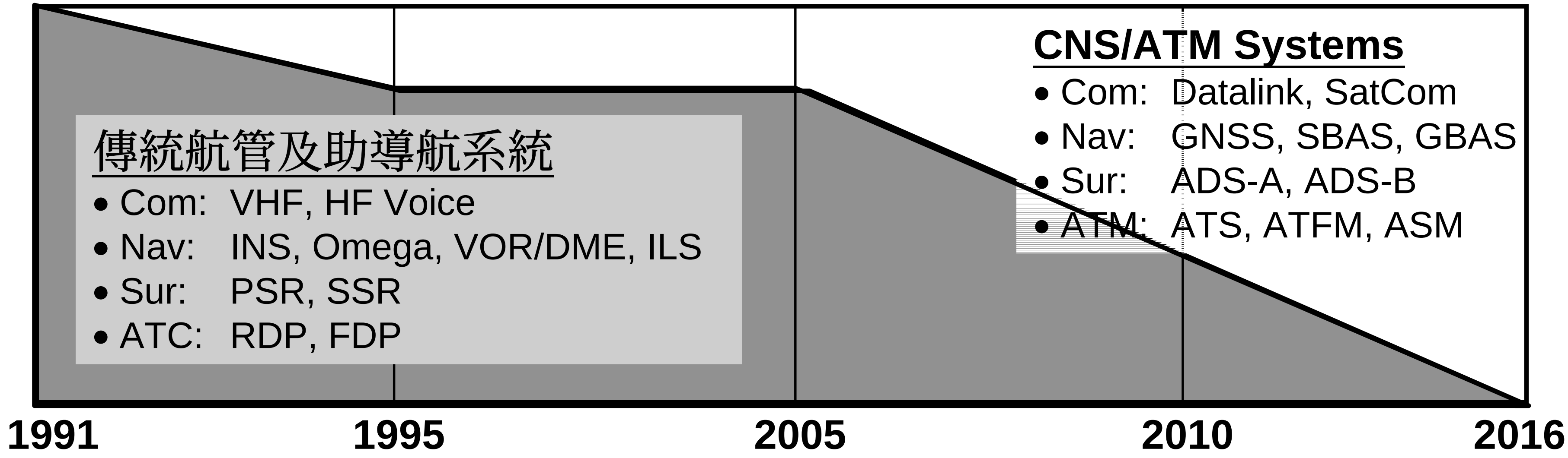
- 監視 [Surveillance]：雷達 ⇒ 自動回報監視

  提供涵蓋全球、無縫隙、無死角之航管監視與空中碰撞預警

- 航管 [Air Traffic Management]：飛航管制 ⇒ 飛航管理

  航管服務(ATS)、空域管理(ASM)、流量管理(ATFM)

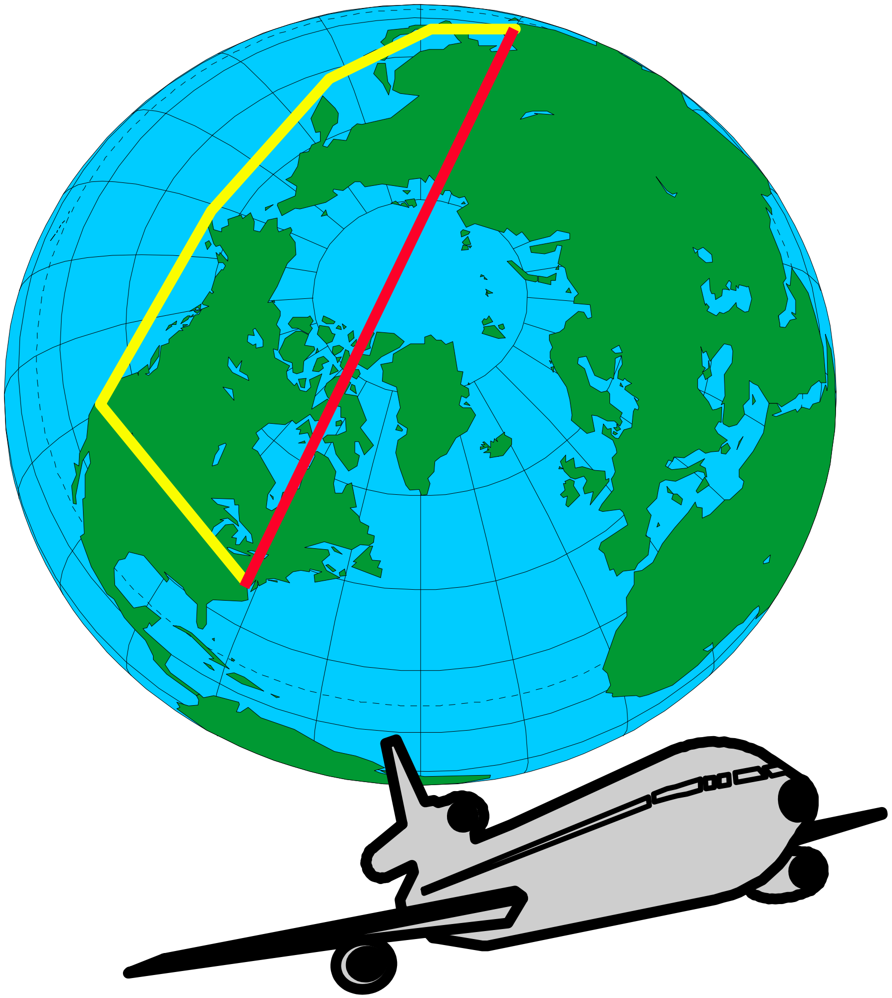
ICAO CNS/ATM 系統更新時程



- 1991-1995 : 發展 CNS/ATM系統技術，並進行實驗及評估
- 1995-2000 : 航機及航管採用部分新系統，作為傳統系統之備分
- 2000-2005 : 新舊系統平行運作，具新設備之航機可從中獲利
- 2005-2016 : 在 CNS/ATM架構下，非必要之傳統系統將逐步淘汰
- 2016 以後 : CNS/ATM系統，將成為國際間之唯一標準

– *Decision on The 10th Air Navigation Conference, Montreal, Canada, Sept 4-20, 1991*
– *ICAO Established CNS/ATM Systems Implementation Task Force (CASITAF) in March, 1994*

CNS/ATM 的經濟效益



New York to Hong Kong

- Conventional Routes
  - 2 Stops in San Francisco & Tokyo
  - 22 Flight Hours
- CNS/ATM Routes
  - No Stops
  - 15 Flight Hours
- Benefits to Air Carrier
  - Operating Savings: $30,000 (Maintenance, Fuel, Crew)
  - Overhead Savings: $20,000 (Airport & Ground Services)
  - 2 Daily Flights, 1 City Pair: $70M/year

Taipei FIR CNS/ATM Implementation Strategy

July 09, 2002

Dr. Youn-Tih Fung
Institute for Information Industry

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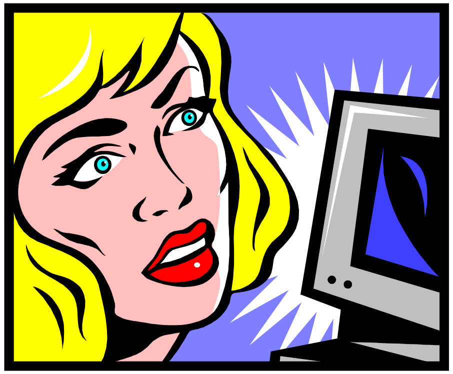
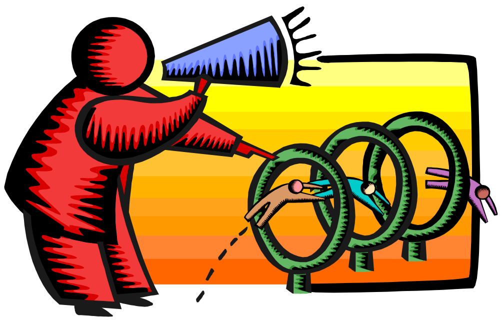
Communication

Limitations in Current Communication



- Lack of data link communication capabilities

- Channel congestion in VHF voice



- Poor quality and reliability in HF voice

Transitions of Communication Systems

<table>
<tr><th>Phase of Flight</th><th>Current Communication Systems</th><th>CNS/ATM Communication Systems</th></tr>
<tr><td>En-Route Oceanic</td><td>•HF (High Frequency) Voice</td><td>•SatCom Voice & Data Link
•HF Voice & Data Link (HFDL)
•Data Link Applications via ATN</td></tr>
<tr><td>En-Route Domestic</td><td rowspan="4">•VHF (Very High Frequency) Voice</td><td rowspan="4">•VHF Voice
•VDL: VHF Digital Link (Data & Voice)
•Data Link Applications via ATN</td></tr>
<tr><td>Terminal</td></tr>
<tr><td>Take-Off & Landing</td></tr>
<tr><td>Airport Surface</td></tr>
</table>

Implementation Strategy - Communication

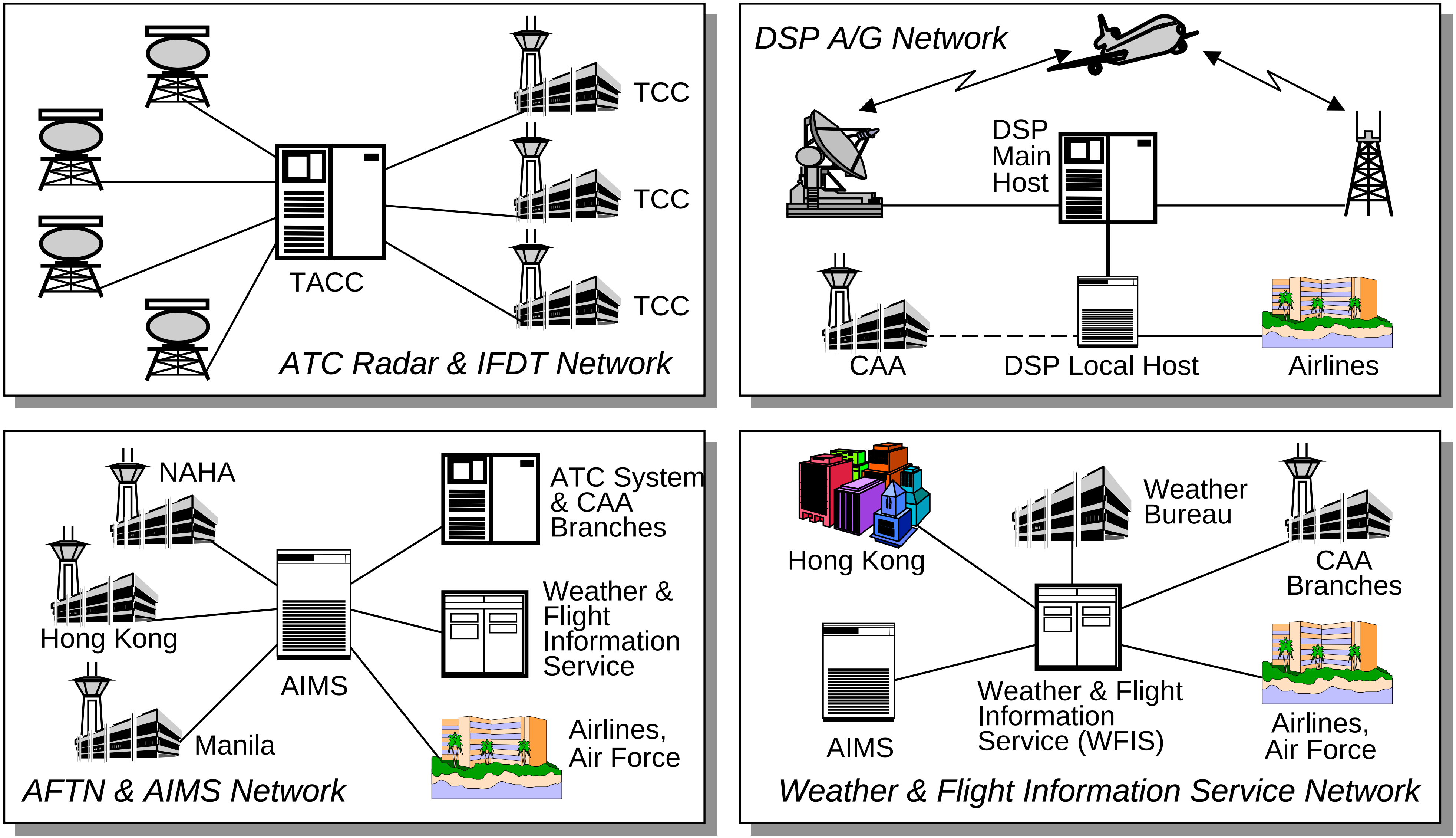
- **Data Link Communication:**
  - Data link service providers (DSP) SITA and ARINC have already provided ACARS and SatCom air-ground data link services for airlines and CAA in Taipei FIR. And they will provide VDL-2 service if market demands.
  - Implement ATN terrestrial intranet for Taipei FIR with AMHS as the first core application to replace AFTN according to ICAO's 2005 schedule.
  - For stand-alone data link application such as D-ATIS and WFIS, implement using current AFTN, CAA's terrestrial intranet & DSP's air-ground networks, and upgrade to FIS when ATN network is ready.
  - For data link applications which require heavy backend ATM processing such as PDC, CM, ADS, CPDLC & AIDC, work with ATM implementation plan using either existing data links or future ATN network.

- **Voice Communication:**
  - Taipei FIR is currently under complete VHF voice communication coverage with no frequency congestion problem.
  - Stay with current VHF voice communication. Should wait for the outcome of VDL-3/8.33kHz battle to determine next generation VHF voice architecture.

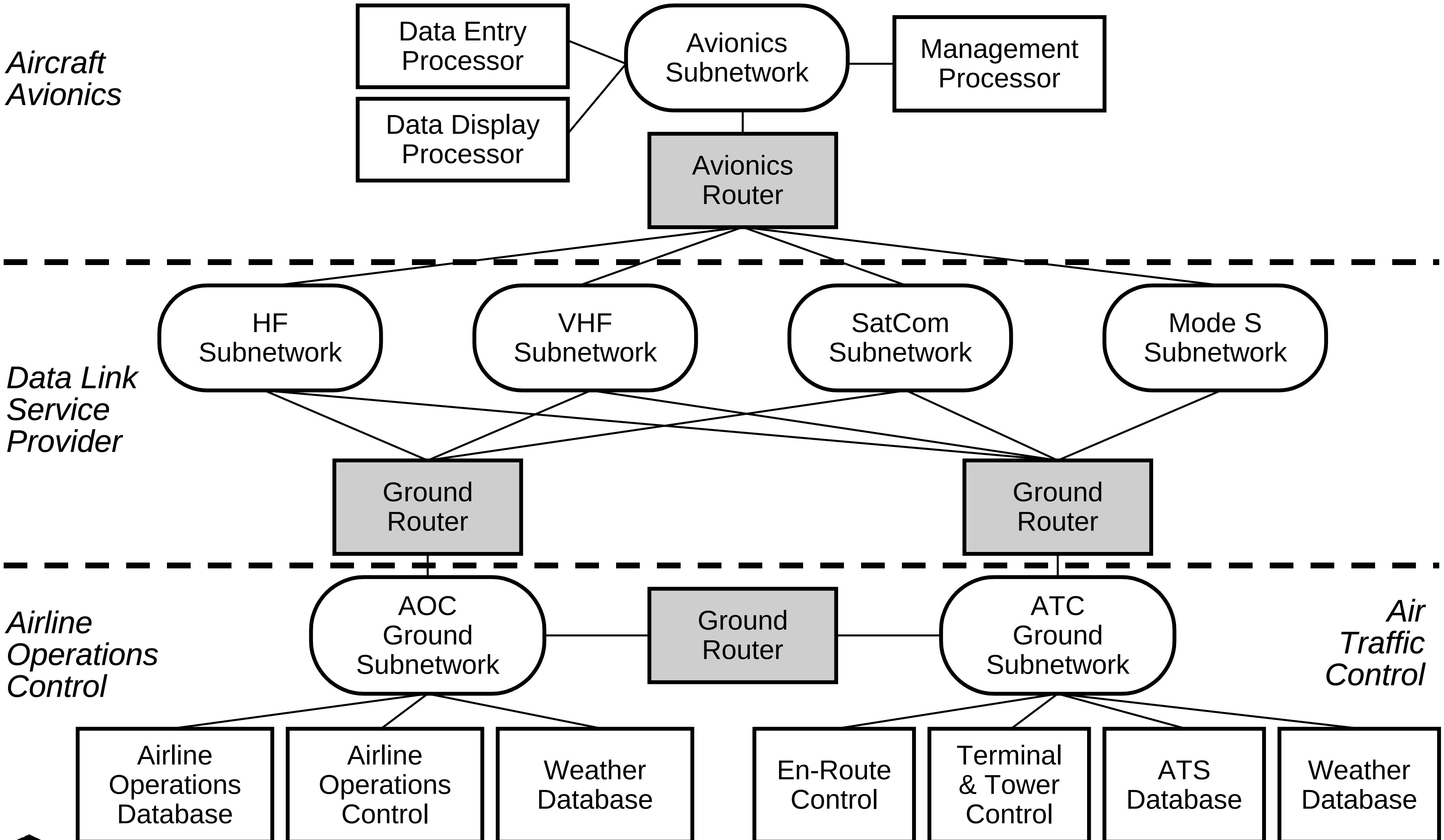
Taipei FIR Communication Summary

VHF Voice Communication		Air-Ground Data Link
• Taipei Area Control Center – Taipei Control (TACC) • Terminal Control Center (TCC) – Taipei Approach (TPE) – Taichung Approach (TCG) – Kaohsiung Approach (KHH) – Hualien Appraoch (HLN) – Taitung Approach (TTN)	• Airport Tower – Sungshan Tower (RCSS) – Taipei Tower (RCTP) – Kaohsiung Tower (RCKH) – Taichung Tower (RCLG) – Chiayi Tower (RCKU) – Tainan Tower (RCNN) – Pingtung South Tower (RCDC) – Hualien Tower (RCYU) – Fengnin Tower (RCFN) – Green Island Tower (RCGI) – Lanyu Tower (RCLY) – Makung Tower (RCQC) – Matsu Tower (RCMT) – Chinmen Tower (RCBS)	• ARINC (ACARS @131.45,131.725MHz) – Taipei CKS-1 (TPE) – Taipei CKS-2 (TPEB) – Taipei Sungshan (TSA) – Kaohsiung (KHH) • SITA (ACARS @131.55 MHz) – Taipei CKS-1 (TPE1) – Taipei CKS-2 (TPE2) – Taipei Sungshan (TSA) – Kaohsiung (KHH) – Hualien (HUN)
ATIS Service		
• VHF Voice ATIS Services – Sungshan Airport (RCSS) – Taipei Airport (RCTP) – Taichung Airport (RCLG) – Kaohsiung Airport (RCKH) – Makung Airport (RCQC) – Chinmen Airport (RCBS)		

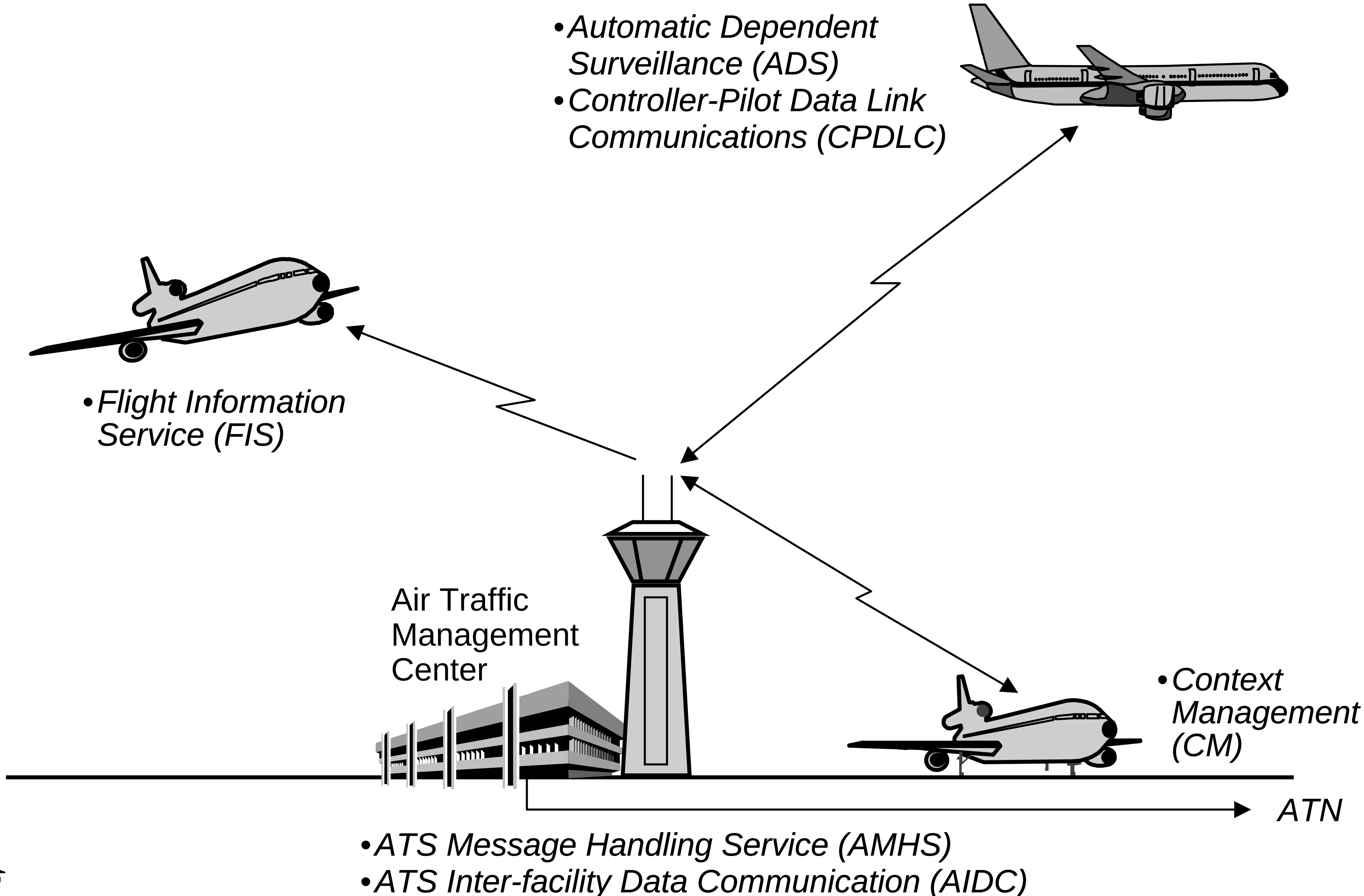
Current Taipei FIR Data Networks



Aeronautical Telecommunication Network (ATN)



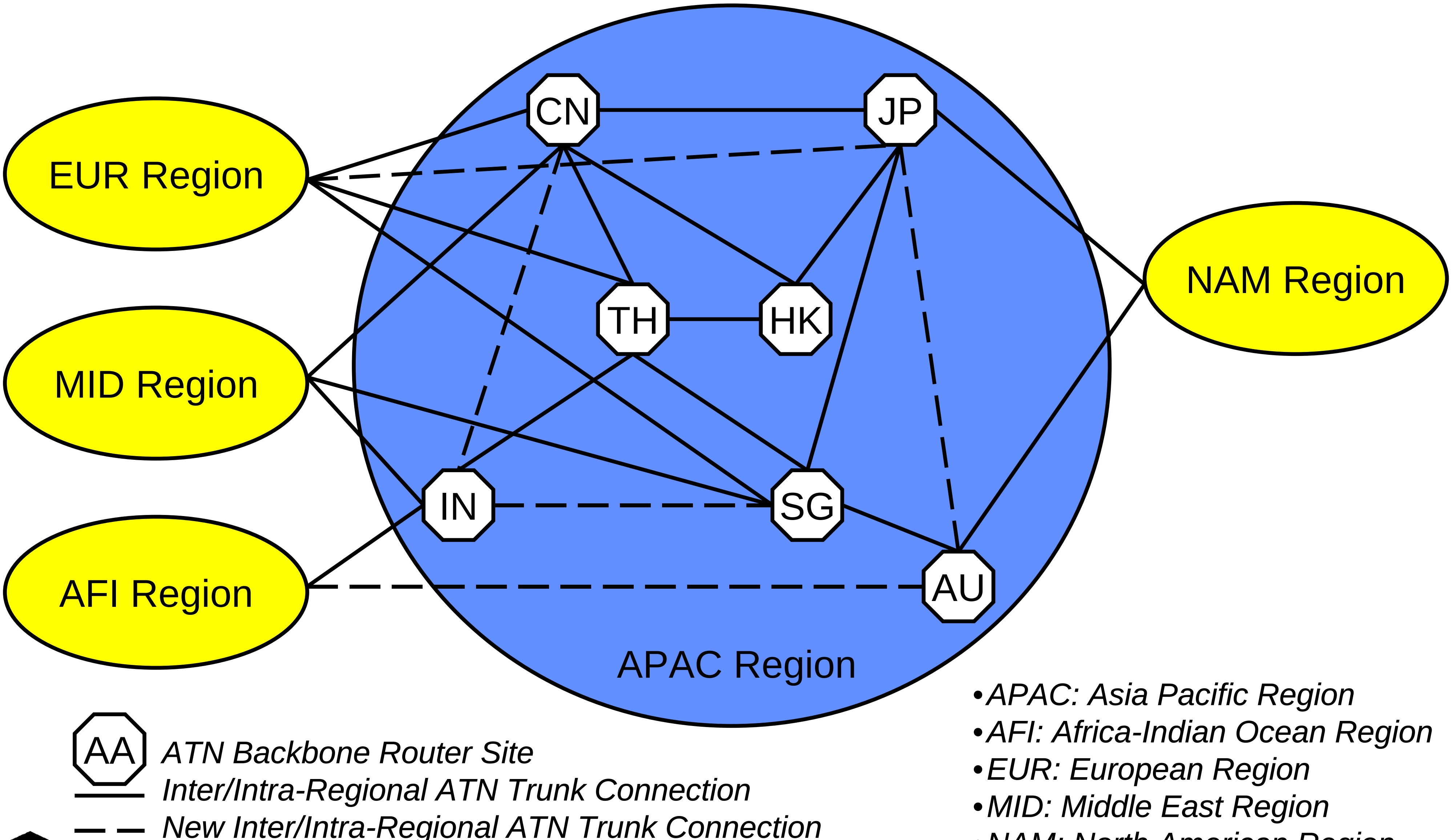
ATN Applications



ATN Application Descriptions

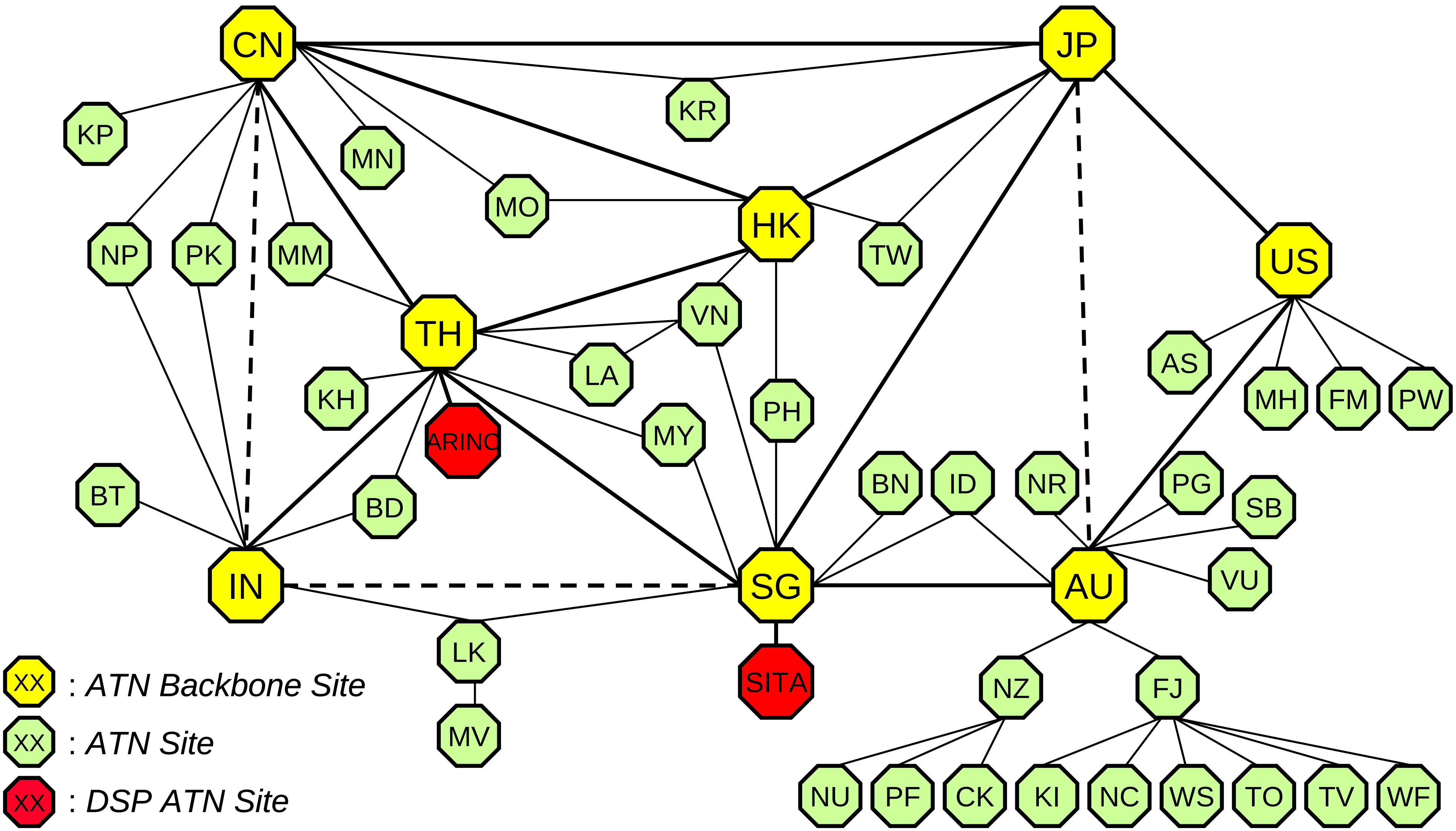
Application	Function	Processing
Context Management (CM)	An air-ground ATN application that provides a logon service allowing initial aircraft introduction into the ATN and a directory of all other data link applications on the aircraft.	ATM
Automatic Dependent Surveillance (ADS)	An air-ground ATN application that provides data from the aircraft to the ATS units for surveillance purposes.	ATM /SDP
Controller Pilot Data Link Communication (CPDLC)	An air-ground ATN application that provides a means of ATC data communication between controlling, receiving or downstream ATS units and the aircraft, using air-ground and ground-ground subnetworks.	ATM /FDP
Flight Information Service (FIS)	An air-ground ATN application that provides to aircraft information and advice useful for the safe and efficient conduct of flight.	FIS
Air Traffic Service (ATS) Message Handling Service (AMHS)	A ground-ground ATN application for ATS organizations to provide the ATS message service.	AMHS
Air Traffic Service (ATS) Inter-facility Data Communication (AIDC)	A ground-ground ATN application dedicated to exchanges between ATS units of ATC information in support of flight notification, flight coordination, transfer of control, transfer of communication, transfer of surveillance data and transfer of general data.	ATM /FDP /SDP /IFDT

Asia-Pacific ATN Backbone Architecture



- *APAC: Asia Pacific Region*
- *AFI: Africa-Indian Ocean Region*
- *EUR: European Region*
- *MID: Middle East Region*
- *NAM: North American Region*

ICAO APAC ATN Implementation Plan



APAC ATN Backbone Implementation (1)

ATN Backbone State	ATN Backbone Connection		Implementation Target Date		Truck Type
	Speed	Protocol	Circuit	BBIS (Router)	
• Australia				• 2003	
• Japan	• 64 kbps	• X.25	• 2003		• Intra-Regional - New
• Singapore	• 64 kbps	• X.25	• 2003		• Intra-Regional - Upgrade
• South Africa	• 192 kbps	• X.25	• 2003		• Inter-Regional - New
• United States	• 64 kbps	• X.25	• 2003		• Inter-Regional - Upgrade
• China				• 2005	
• Japan	• 64 kbps	• X.25	• 2005		• Intra-Regional - Upgrade
• Hong Kong, China	• 64 kbps	• X.25	• 2005		• Intra-Regional - Upgrade
• India	• 64 kbps	• X.25	• 2005		• Intra-Regional - New
• Russia Federation	• 192 kbps	• X.25	• 2005		• Inter-Regional - Upgrade
• Thailand	• 64 kbps	• X.25	• 2002		• Intra-Regional - New
• Hong Kong, China				• 2003	
• China	• 64 kbps	• X.25	• 2005		• Intra-Regional - Upgrade
• Japan	• 64 kbps	• X.25	• 2003		• Intra-Regional - Upgrade
• Thailand	• 64 kbps	• X.25	• 2003		• Intra-Regional - Upgrade
• India				• 2005	
• China	• 64 kbps	• X.25	• 2005		• Intra-Regional - New
• Kenya - Nairobi	• 192 kbps	• X.25	• 2005		• Inter-Regional - Upgrade
• Oman - Muscat	• 192 kbps	• X.25	• 2005		• Inter-Regional - Upgrade
• Singapore	• 64 kbps	• X.25	• 2005		• Intra-Regional - New
• Thailand	• 64 kbps	• X.25	• 2003		• Intra-Regional - Upgrade

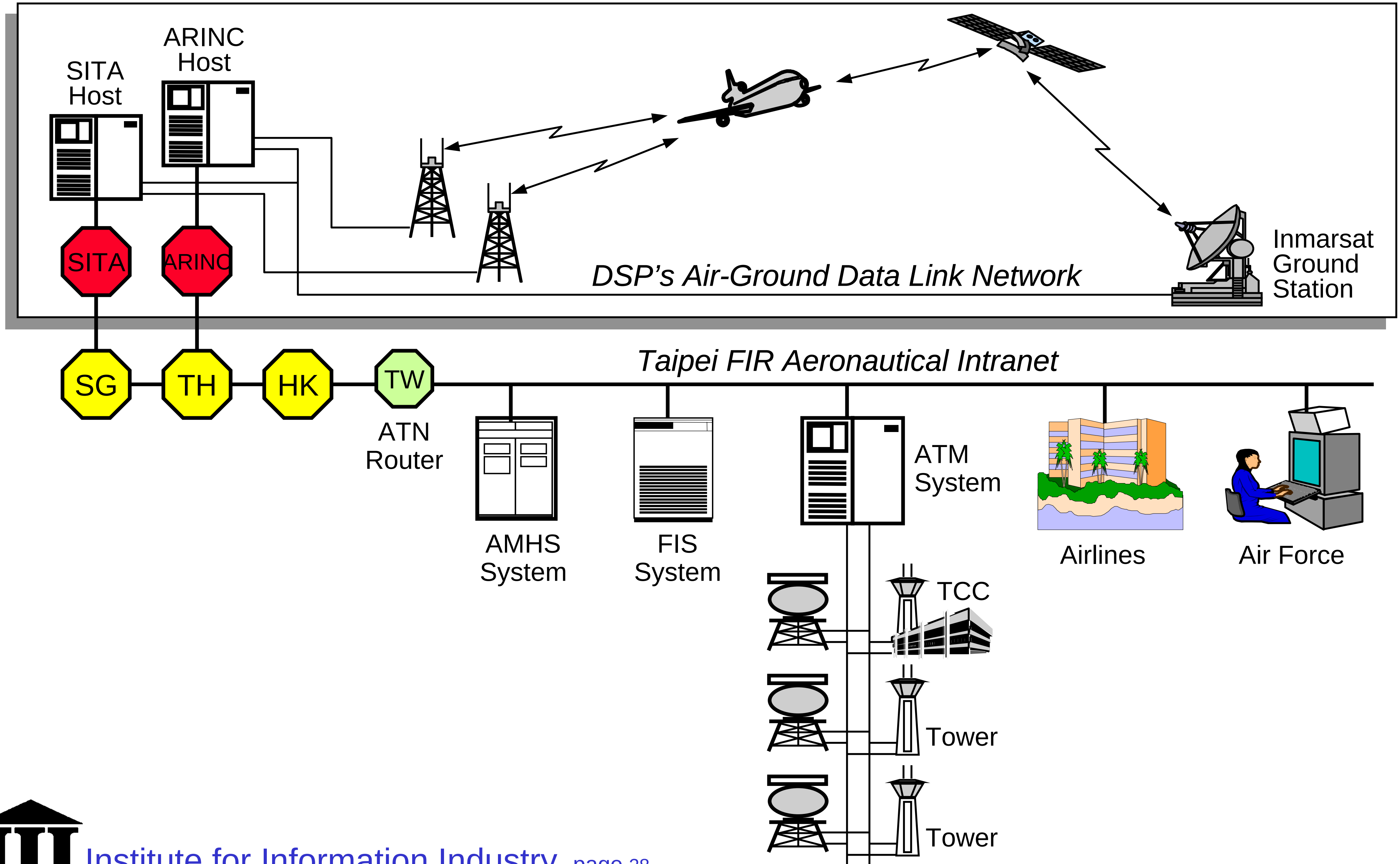
APAC ATN Backbone Implementation (2)

ATN Backbone State	ATN Backbone Connection		Implementation Target Date		Truck Type
	Speed	Protocol	Circuit	BBIS (Router)	
• Japan • Australia • China • Hong Kong, China • Europe • Singapore • Russia Federation • United States	 • 64 kbps • 64 kbps • 64 kbps • 64 kbps • 64 kbps • 192 kbps • 64 kbps	 • X.25 • X.25 • X.25 • X.25 • X.25 • X.25 • X.25	 • 2003 • 2005 • 2003 • 2005 • 2003 • 2005 • 2003	• 2002	 • Intra-Regional - New • Intra-Regional - Upgrade • Intra-Regional - Upgrade • Inter-Regional - New • Intra-Regional - Upgrade • Inter-Regional - New • Inter-Regional - Upgrade
• Singapore • Australia • Bahrain • England - London • Japan • India • Thailand	 • 64 kbps • 192 kbps • 64 kbps • 64 kbps • 64 kbps • 64 kbps	 • X.25 • X.25 • X.25 • X.25 • X.25 • X.25	 • 2003 • 2005 • 2005 • 2003 • 2005 • 2003	• 2005	 • Intra-Regional - Upgrade • Inter-Regional - Upgrade • Inter-Regional - Upgrade • Intra-Regional - Upgrade • Intra-Regional - New • Intra-Regional - Upgrade
• Thailand • China • Hong Kong, China • India • Italy-Rome • Singapore	 • 64 kbps • 64 kbps • 64 kbps • 64 kbps • 64 kbps	 • X.25 • X.25 • X.25 • X.25 • X.25	 • 2002 • 2003 • 2005 • 2005 • 2003	• 2002	 • Intra-Regional - New • Intra-Regional - Upgrade • Intra-Regional - Upgrade • Inter-Regional - Upgrade • Intra-Regional - Upgrade
• Chinese Taipei • Japan • Hong Kong, China	 • 9.6 kbps • 9.6 kbps	 • X.25 • X.25	 • 2005 • 2005	• 2005	 • Intra-Regional - Upgrade • Intra-Regional - Upgrade

APAC Country ISO Code

Country	ISO Code	Country	ISO Code
American Samoa	AS	Mongolia	MN
Australia	AU	Myanmar	MM
Bangladesh	BD	Nauru	NR
Bhutan	BT	Nepal	NP
Brunei Darussalam	BN	New Caledonia	NC
Cambodia	KH	New Zealand	NZ
China	CN	Niue	NU
Cook Islands	CK	Pakistan	PK
Fiji	FJ	Palau	PW
French Polynesia	PF	Papua New Guinea	PG
Hong Kong China	HK	Philippines	PH
India	IN	Samoa	WS
Indonesia	ID	Singapore	SG
Japan	JP	Solomon Islands	SB
Kiribati	KI	Sri Lanka	LK
Democratic People's Republic of Korea	KP	Chinese Taipei	TW
Republic of Korea	KR	Thailand	TH
Lao	LA	Tonga	TO
Macau China	MO	Tuvalu	TV
Malaysia	MY	United States	US
Maldive Islands	MV	Vanuatu	VU
Marshall Islands	MH	Viet Nam	VN
Federated States of Micronesia	FM	Wallis and Futuna Islands	WF

Taipei FIR ATN Network Architecture

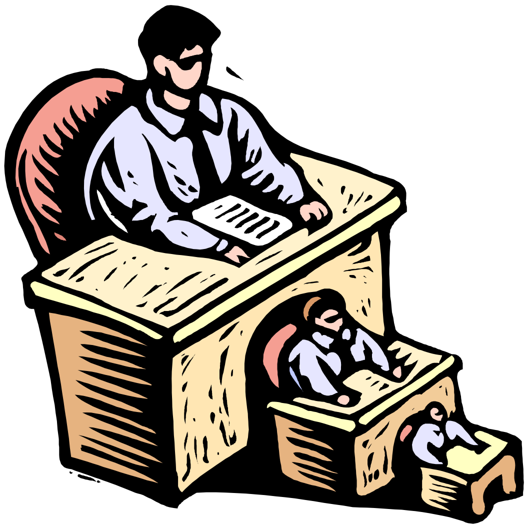


Comparison of ATC VDL Solutions

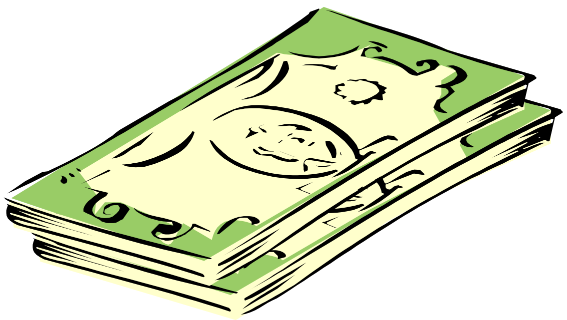
Function	FAA: VDL-3 NEXCOM	Eurocontrol: 8.33kHz plus VDL-2
Anti-Blocking	• Prevent the advertent simultaneous and unintentional transmission of VHF transmissions	• A device (Contran) exists for analog adios that approximate this feature • Not integrated or costed in 8.33 program
Stuck Microphone	• Reset aircraft radio after pilot unaware stuck microphone – channel automatically cleared after 35 seconds	• Timer could be implemented for analog radios • Not integrated or costed in 8.33 program
Controller Override	• Controller capability to obtain access to communication channel, pre-empty other users	• Not feasible for 8.33kHz/VDL-2
Next Channel Uplink (Auto Tune)	• Automatically send next channel to aircraft radio without pilot intervention for transfer to next ATC control sector	• Not feasible in 8.33kHz • Optional equipage with VDL-2/CPDLC • Requires CPDLC connect to radio control
Urgent Downlink Request	• Pilot is capable to request urgent access to occupied communication channel	• Not feasible for 8.33kHz • Pilot can use Free Text Downlinks in VDL-2/CPDLC
Integrated Voice and Data	• Single provisioned communication channel can provide both voice and data services to an aircraft	• Build out of VDL-2 network to provide data coverage for all areas with voice coverage
ATC Priority Queuing	• Permits priority handling, predictable performance, and robust communications for ATC data link	• Not feasible for 8.33kHz • VDL-2 performance limited by CSMA protocol

Navigation

Limitations in Current Navigation



- Different navigation accuracies & separation standards in different phases of flight

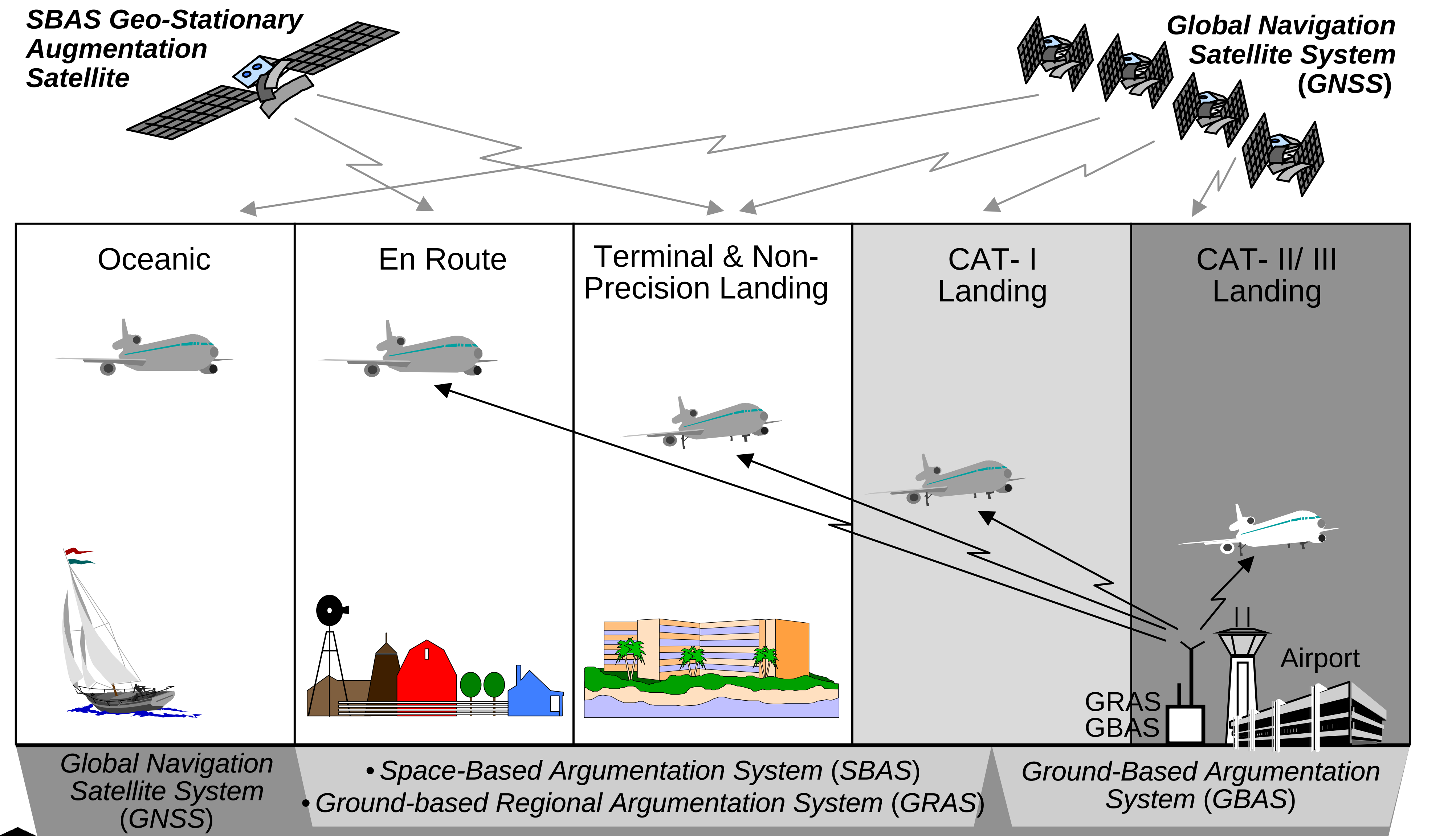


- Many systems, expensive to purchase, operate and maintain

Transitions of Navigation Systems

Phase of Flight	Current Navigation Systems	CNS/ATM Navigation Systems
En-Route Oceanic	• IRS: Inertial Reference System • OMEGA: OMEGA Navigation System	• GNSS: Global Navigation Satellite System
En-Route Domestic	• VOR/DME: VHF Omni-directional Range/ Distance Measuring Equipment • TACAN: Tactical Air Navigation • VORTAC: Combined VOR/TACAN • NDB: Non-Directional Beacon	• GNSS • SBAS: Space-Based Augmentation System • GRAS: Ground-based Regional Augmentation System
Terminal		
Landing Aid	• ILS: Instrument Landing System • Runway Lighting	• GNSS • GBAS: Ground-Based Augmentation System • Airport Surface Lighting
Airport Surface	• Airport Surface Lighting	

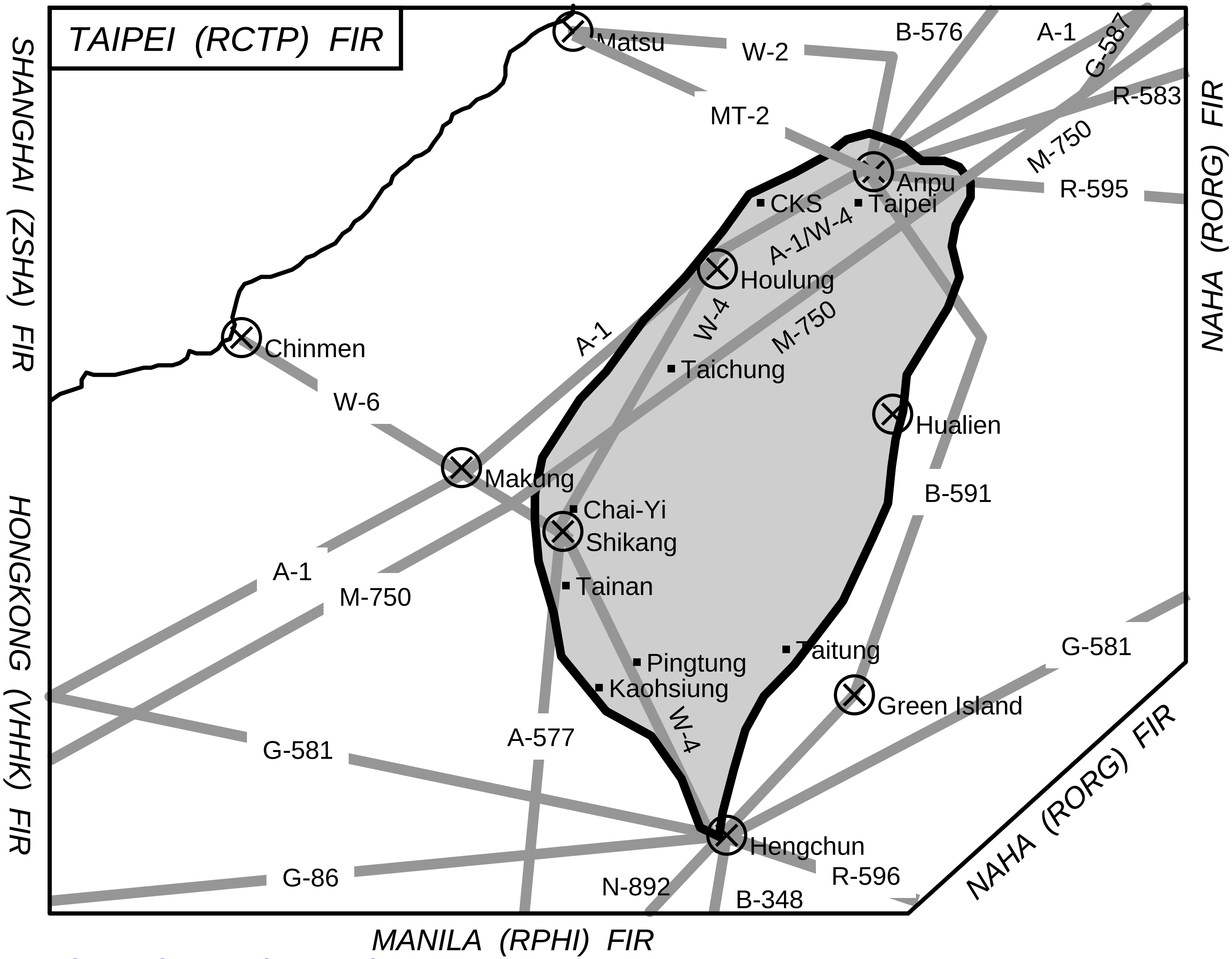
Final Goal of Navigation in CNS/ATM



Implementation Strategy - Navigation

- **Classic Ground-Based Naviads:**
  - Very good existing enroute ground-based navaids coverage in Taipei FIR.
  - Need more naviads for precision/non-precision approaching & landing
- **GNSS Navigation:**
  - CAA already published 20 GPS procedures including RNAV and NPA (non-precision approach) procedures for 8 civil airports throughout Taipei FIR, but has no guarantee in service accuracy, continuity, availability and integrity.
  - Setup a evaluation system to determine the necessity and architecture of GNSS augmentation in Taipei FIR:
    - Collects GPS data in critical areas
    - Establish GNSS analysis model and simulate the GNSS accuracy, availability, integrity, and continuity of service for all candidates of augmentation architecture in Taipei FIR
    - Determine the best GNSS augmentation architecture for Taipei FIR
    - Define implementation plan, technical specifications, and associated regulations and procedures for the selected augmentation systems
  - Based-on the recommendation of the above analysis, implement our own GRAS or work with Japan MSAS (MTSAT Satellite-based Augmentation System) to implement SBAS for en-route and terminal GNSS navigation.
  - For precision landing aid, Implement GBAS CAT-I/II in Taipei CKS airport first, and in other airports if necessary.

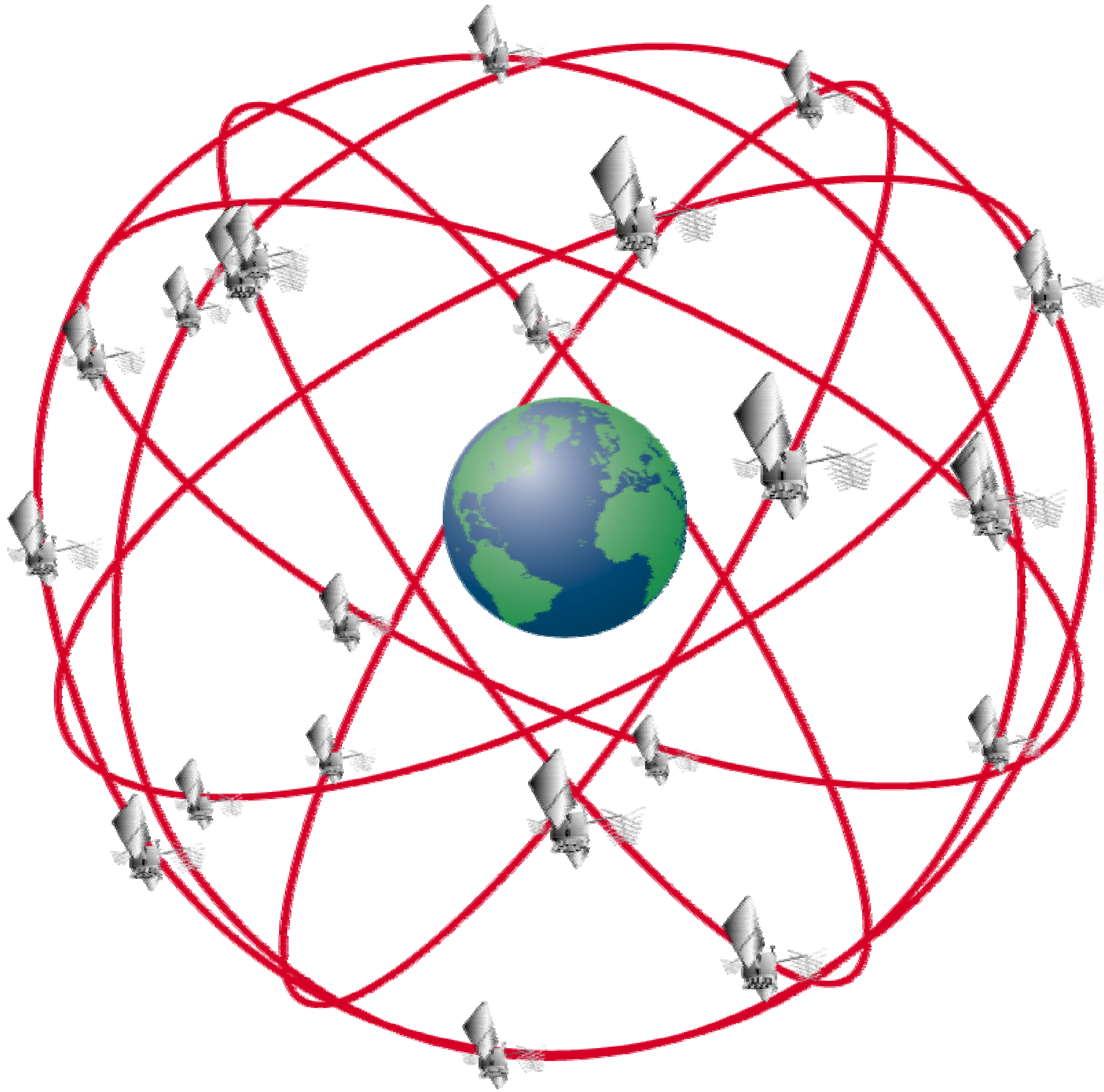
Current Taipei FIR Navaids



Taipei FIR Navaids Summary

En-Route NDB	En-Route VOR/DME	Airport ILS, MLS
• NDB [9] – Anpu (AP) – Houlung (HL) – Makung (BM) – Shikang (NN) – Hengchun (KW) – Hualien (YU) – Green Island (GI) – Matsu (MT) – Chinmen (BS)	• VOR/DME [3] – Anpu (APU) – Makung (MKG) – Hualien (YLN) • VORTAC [4] – Houlung (HLG) – Shikang (TNN) – Hengchun (HCN) – Green Island (GID) • DME [1] – Matsu (MTS)	• ILS CAT-II – Taipei CKS RCTP (CKS) 05 – Taipei CKS RCTP (CKS) 23 • ILS CAT-I – Taipei Sungshan RCSS (TSA) 10 – Taipei Sungshan RCSS (TSA) 28 – Taipei CKS RCTP (CKS) 06 – Taipei CKS RCTP (CKS) 24 – Chia-Yi RCKU (CYI) 36 – Tainan RCNN (TNN) 36R – Kaohsiung RCKH (KHH) 09L – Kaohsiung RCKH (KHH) 27R – Pingtung RCDC (PIF) 09 – Makung RCQC (MZG) 02 • MLS – Taichung RCLG (TXG) 36 – Hualien RCYU (HUN) 03 – Taitung RCFN (TTT) 04

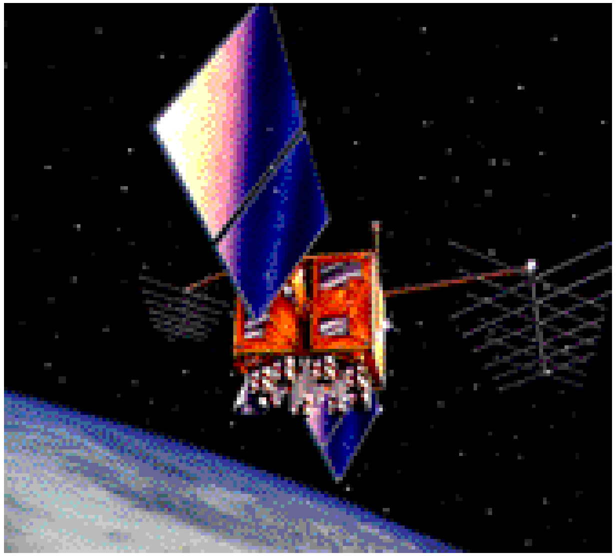
Global Satellite Navigation System (GNSS)



GNSS System Comparison

	GPS (Global Positioning System)	GLONASS (Global Orbiting Navigation Satellite System)
No. of Satellites	21+3 (Operational+Spare)	21+3 (Operational+Spare)
No. of Orbital Planes	6	3
Satellites per Plane	4 (uneven)	8 (even)
Orbital Inclination	55 degrees	64.8 degrees
Orbital Radius	26560 km	25510 km
Orbital Period	11H 58M	11H 15M
Time Reference	UTC (USNO)	UTC (SU)
Geodetic Datum	WGS-84	PZ-90
Signal Separation Technique	CDMA	FDMA
Carrier Frequency	L1: 1575.42 MHz (P,C/A,M) L2: 1227.60 MHz (P,C/A,M) L5: 1176.45 MHz (C/A)	L1:1602.5~1615.5 MHz (P,C/A) L2:1246.4~1256.5 MHz (P)
Time Accuracy	PPS:200, SPS:340 nsec	1 μsec
Horizontal Position Accuracy	PPS:17.8m, SPS:100m	100 m
Vertical Position Accuracy	PPS:27.7m, SPS:156m	150 m
Velocity Accuracy	20 cm/sec	15 cm/sec

GPS Satellite Modernization



Block II/IIA

- All have been launched
- Rockwell (now Boeing)
- First launch Feb 1989
- 22 on orbit
- Mean Mission Duration (MMD) 6.0/8.6/10.6 yrs

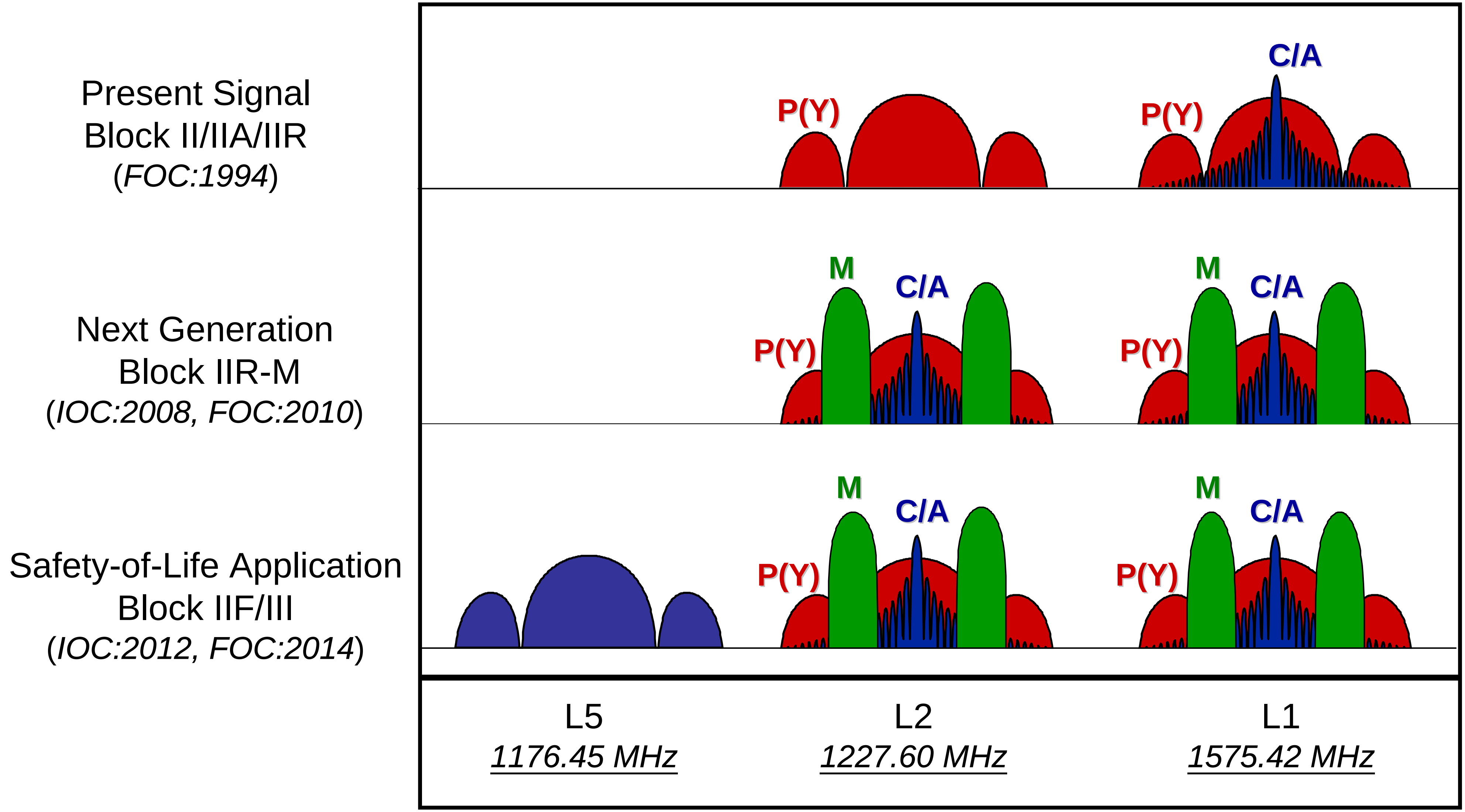
Block IIR

- In production
- Lockheed Martin
- 21 procured
- 6 on orbit
- 1 destroyed on launch
- MMD 7.8 years

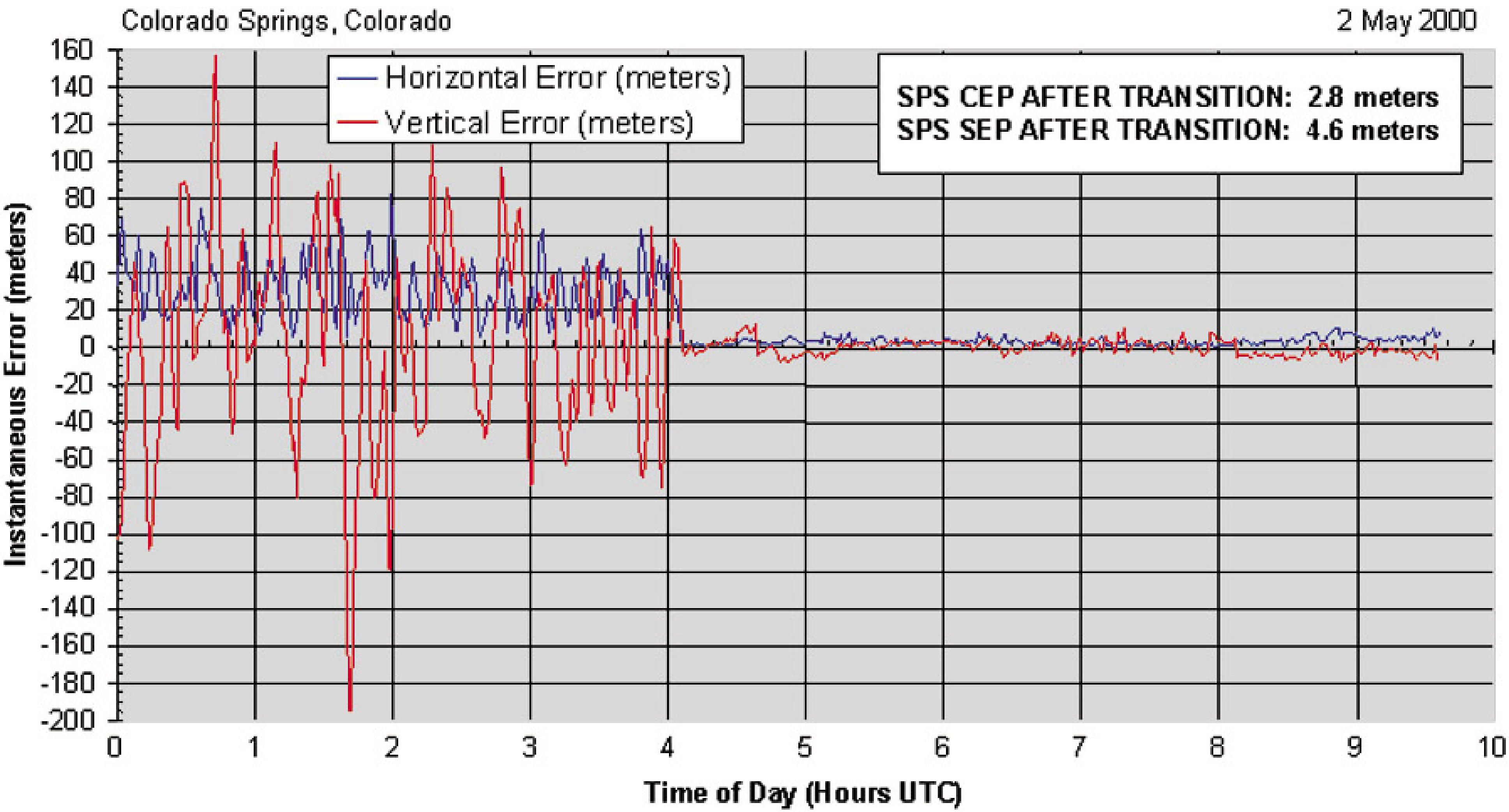
Block IIF

- In development
- Boeing
- 6 already procured
- Options for 6 more
- 12-year design life
- MMD 10 years

GPS Signal Modernization



SA Transition -- 2 May 2000



GNSS for Civil Aviation Navigation

- **A navigation system for civil aviation should be (ICAO A32-19):**

  States shall ensure the continuity, availability, integrity, accuracy and reliability of GNSS services.
  - Available everywhere (Availability)
  - Available all the time (Continuity)
  - Extremely accurate (Accuracy)
  - Trusted (Integrity)

- **Current GPS and GLONASS constellations cannot support requirements for all phases of flight:**
  - Integrity is not guaranteed
    - Not all satellites are monitored at all times
    - Time-to-alarm is from minutes to hours
    - No automatic notification of GNSS errors to users
  - Accuracy is not sufficient
    - Even with SA off, vertical accuracy > 10m
  - Availability and continuity must meet aviation requirements

Required Navigation Performance (RNP)

	Oceanic	En-Route	Terminal	Non Precision	CAT-I Landing	CAT-II Landing	CAT-III Landing
Operational System	GNSS & RAIM	SBAS/ GRAS	SBAS/ GRAS	SBAS/ GRAS	GBAS	GBAS	GBAS
Augmentation Broadcast Media	None	SatCom/ VHF	SatCom/ VHF	SatCom/ VHF	VHF	VHF	VHF
Vertical Accuracy (95%)	12.4 NM	2.0 NM	0.4 NM	220 m	7.6 m	2.0 m	2.0 m
Lateral Accuracy (95%)	12.4 NM	2.0 NM	0.4 NM	220 m	16.0 m	6.9 m	6.1 m
Time-to-Alert	120 sec	60 sec	30 sec	10 sec	6 sec	2 sec	2 sec
Alert Limit	H=12.4NM	H=2.0NM	H=1.0NM	H=0.3NM	H=40m V=10-15m	H=17.3m V=5.3m	H=15.5m V=5.3m
Integrity	10^{-5}/hr	10^{-7}/hr	10^{-7}/hr	10^{-7}/hr	2×10^{-7}/app	2×10^{-9}/app	2×10^{-9}/app
Continuity	1×10^{-5}/hr	1×10^{-6}/hr	1×10^{-6}/hr	1×10^{-5}/hr	5×10^{-5}/app	4×10^{-6}/15s	2×10^{-6}/15s
Availability*	0.99-0.99999	0.999-0.99999		0.99-0.99999			

** 0.99=4days/year, 0.999=9hour/year, 0.99999=5min/year*

GNSS for Civil Aviation Use

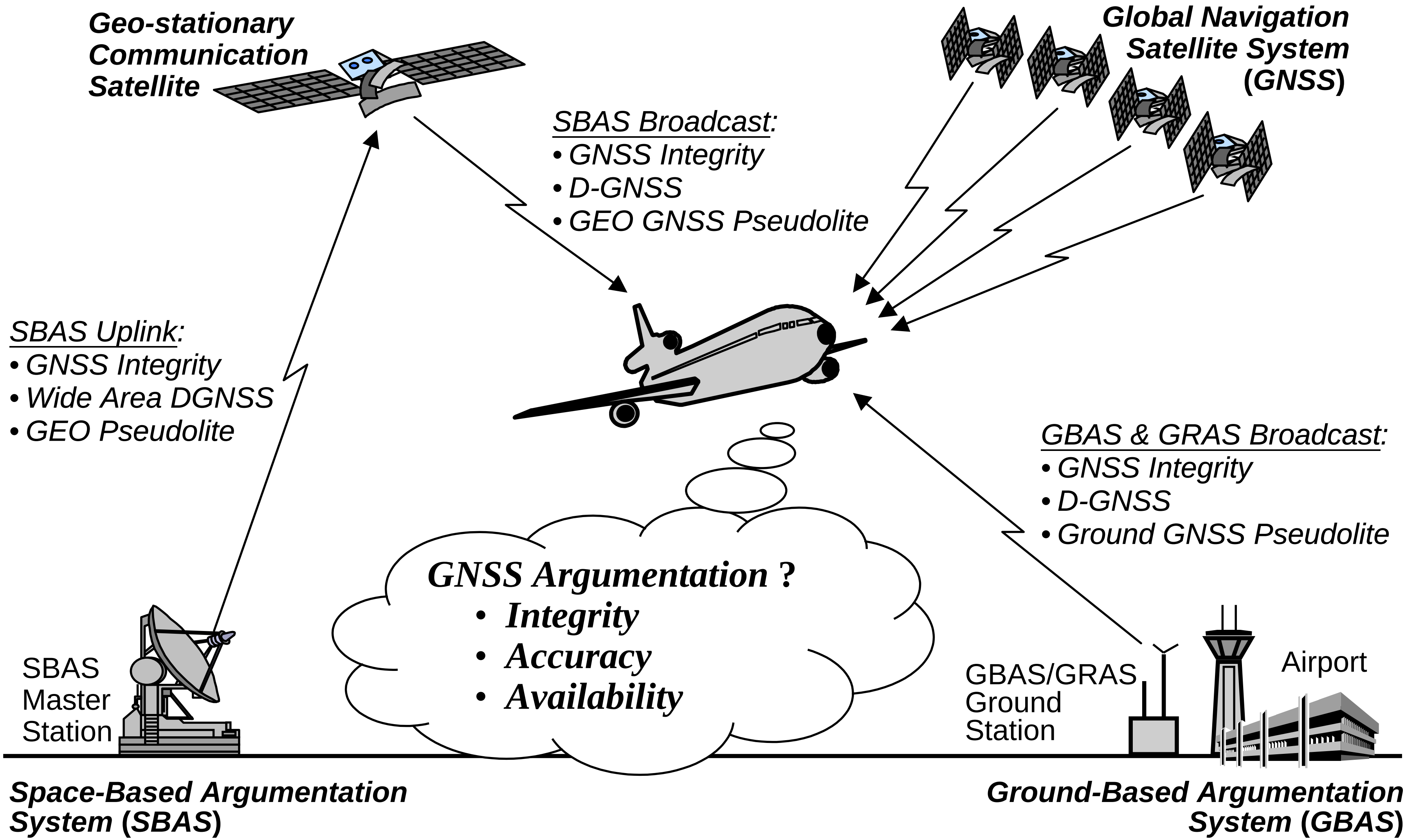
Phases of Flight		Primary Means of Navigation		
		Integrity	Availability	Accuracy
En-Route	RNP 10-20			
	RNP 2-5			
Approach & Landing	Non-Precision Approaches			
	CAT-I Precision Approaches			
	CAT-II & III Precision Approaches			
Surface	Ground Movement			

GPS & RAIM

SBAS or GRAS

GBAS

GNSS Augmentation for Air Navigation



GNSS Augmentation Systems

- ***Aircraft-Based Augmentation System (ABAS)*:**
  Aircraft using INS to augment GNSS (AAIM) or GNSS receiver maintaining self awareness of GNSS integrity by satellite position comparison (RAIM):
  - AAIM: Aircraft Autonomous Integrity Monitoring (AAIM)
  - RAIM: Receiver Autonomous Integrity Monitoring (RAIM)

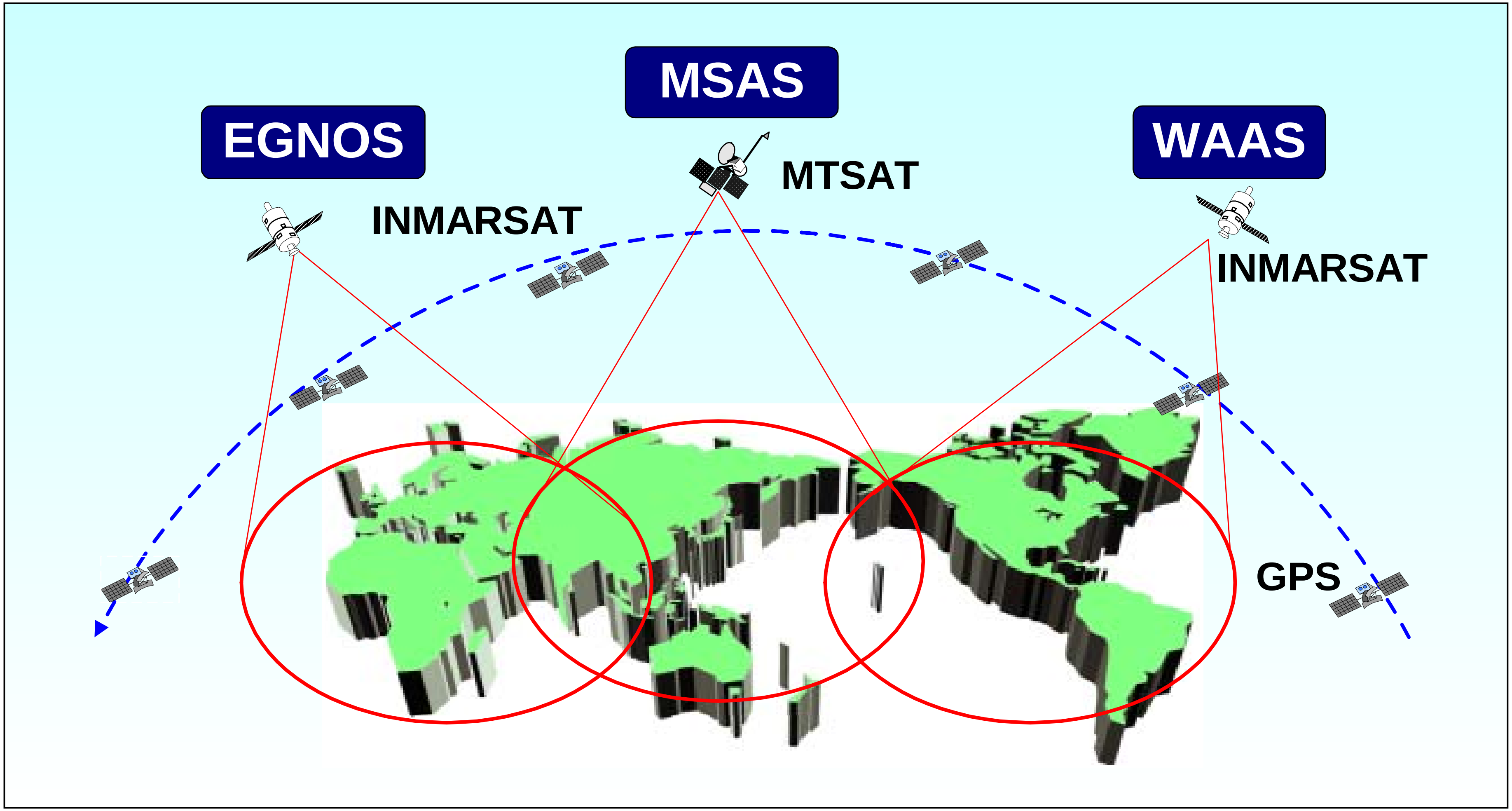
- ***Space-Based Augmentation System (SBAS)*:**
  A space-based wide-area GNSS augmentation system to provide navigation service for en-route, approach & non-precision landing using L-band satellite broadcast link:
  - US: Wide Area Augmentation System (WAAS)
  - Japan: MTSAT Satellite-based Augmentation System (MSAS)
  - Europe: European Geo-stationary Navigation Overlay Service (EGNOS)

- ***Ground-based Regional Augmentation System (GRAS)*:**
  A ground-based wide-area GNSS augmentation system to provide navigation service for en-route, approach & non-precision landing using VHF Data Broadcast Link (VDB):
  - Australia: Ground-based Regional Augmentation System (GRAS)

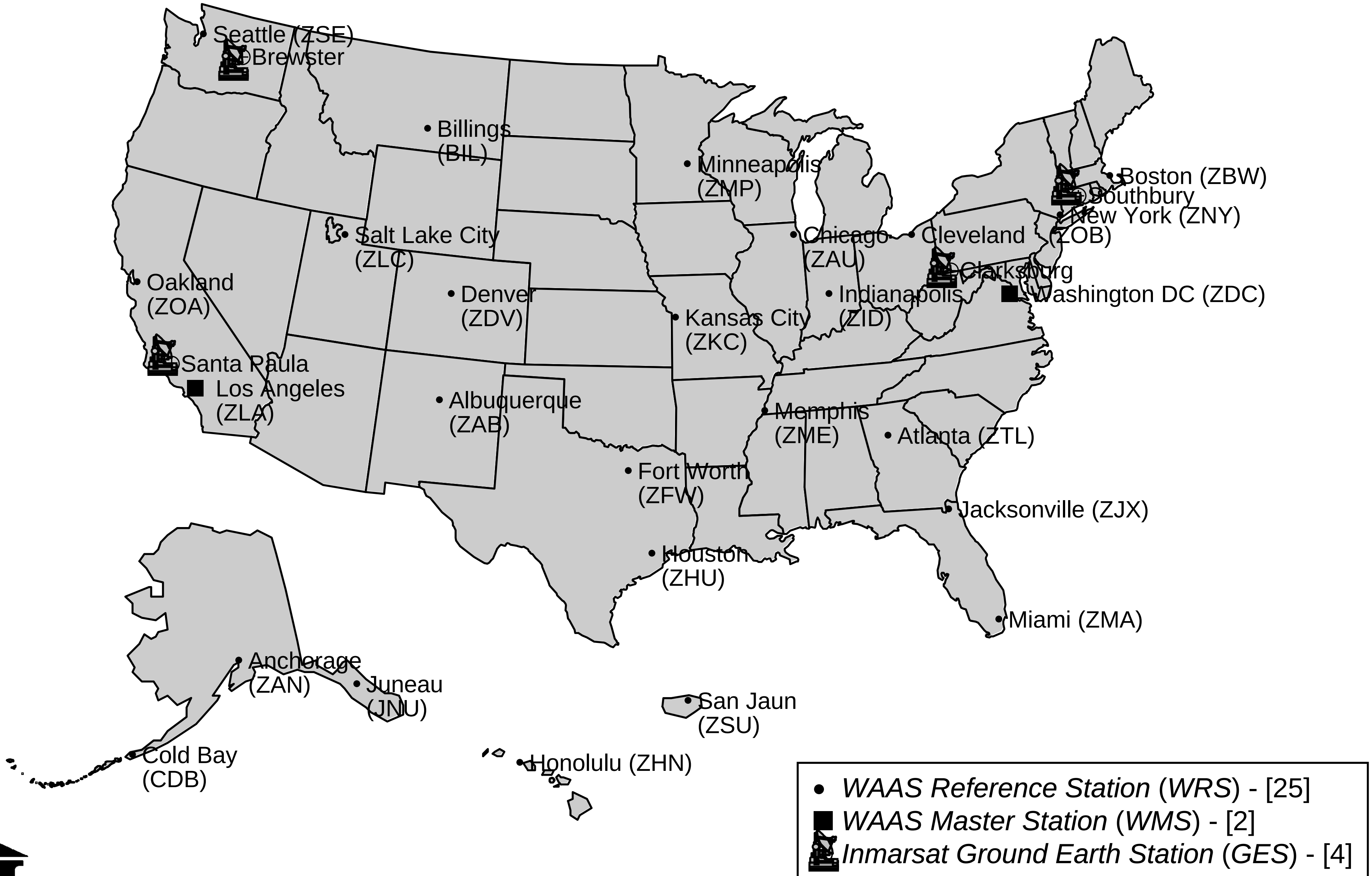
- ***Ground-Based Augmentation System (GBAS)*:**
  A ground-based local-area GNSS augmentation system to provide approach & CAT-I/II/III precision landing service in an airport area using VHF Data Broadcast Link (VDB):
  - US FAA: Local Area Augmentation System (LAAS)
  - US DOD: Joint Precision Approach and Landing System (JPALS)

Interoperability Among SBASs

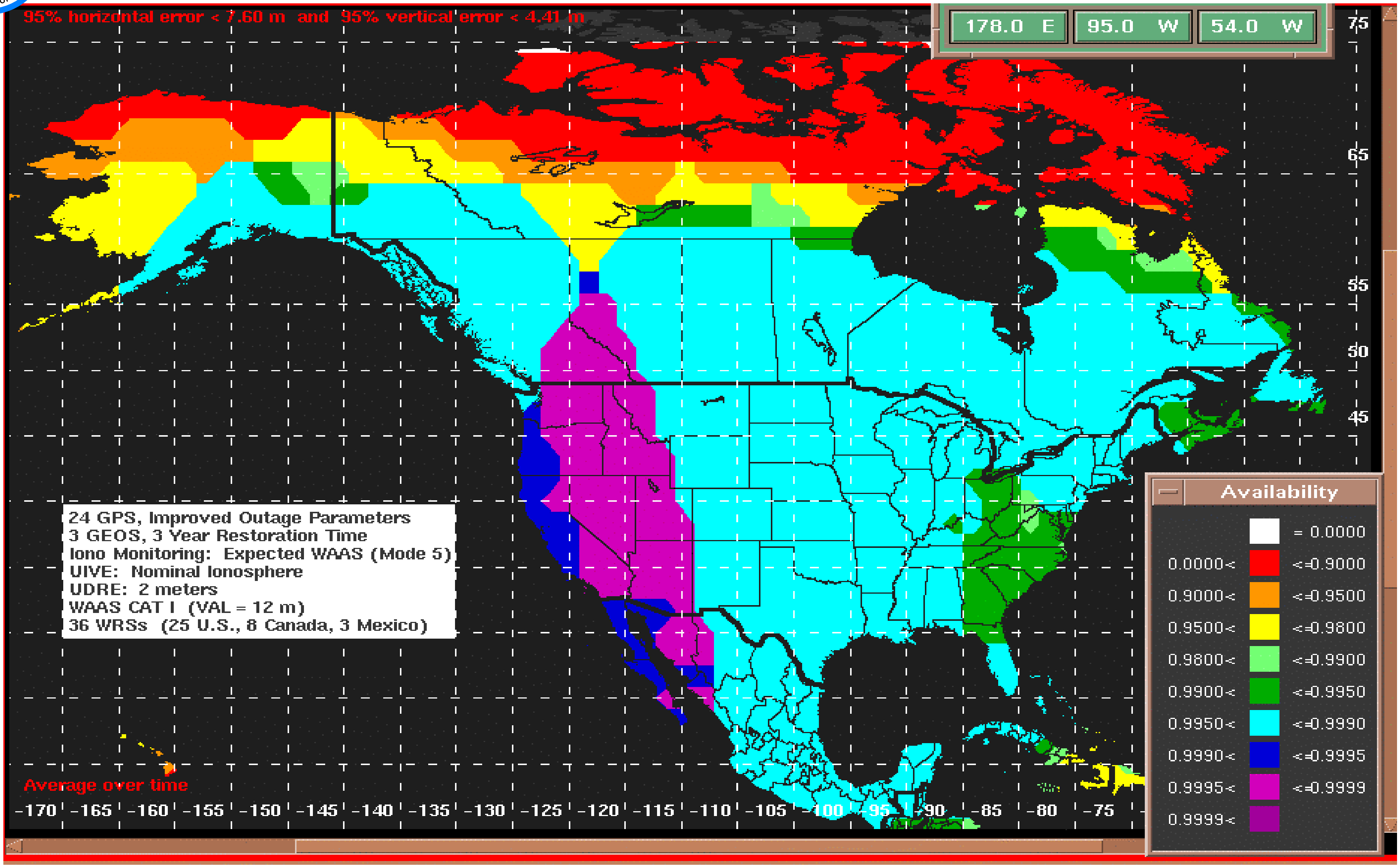
US WAAS, European EGNOS and Japan MSAS are interoperable at the level of signal in space



Wide Area Augmentation System (WAAS)



WAAS CAT-I Availability with 3 GEOs



- WAAS has only 2 INMARSAT GEOs (AOR-W & POR) Today

WAAS Instrument Approach Services

- **GLS (GNSS Landing System) - Equivalent of ILS CAT-I**
  – Requires 40 m horizontal and 12 m vertical integrity
  – Unattainable until L5 is implemented (2012-2013)

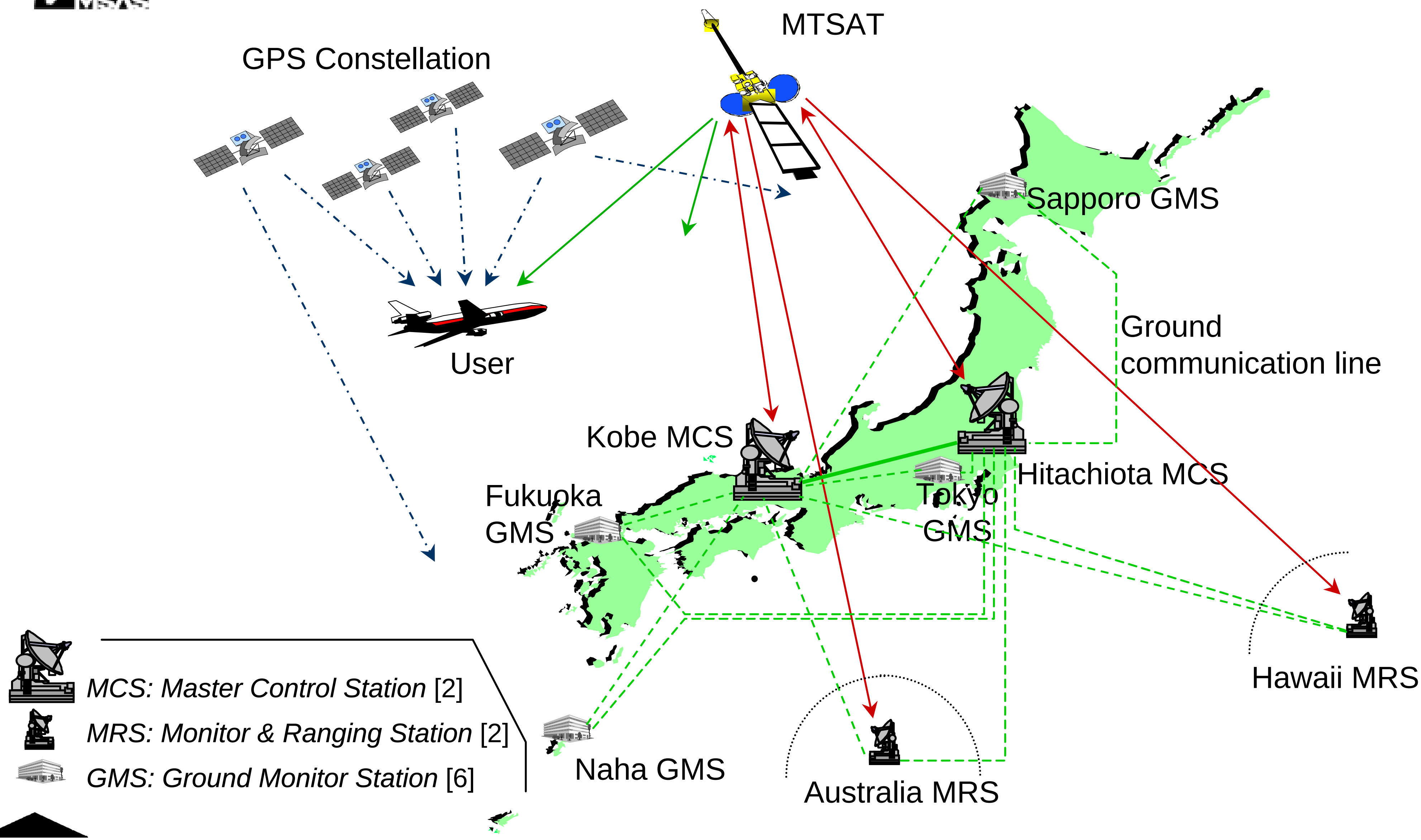
- **APV-2 (LNAV/VNAV(Lateral/Vertical Navigation))**
  – Requires 40 m horizontal and 20 m vertical integrity
  – 20 m vertical integrity requires improvements in WAAS

- **APV-1.5: Now called LPV (Lateral Precision with Vertical Guidance)**
  – Requires 40 m horizontal and 50 m vertical integrity
  – Attainable with WAAS Phase I with no further development

- **APV-1 (LNAV/VNAV(Lateral/Vertical Navigation))**
  – Requires 556 m horizontal and 50 m vertical integrity
  – Requires SBAS or Baro/VNAV (GPS or DME/DME and Baro)

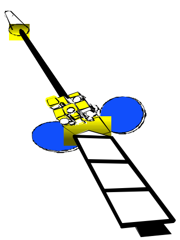
- **LNAV (Lateral Navigation) – Non-Precision Approach**
  – Requires 556 m HAL
  – No vertical guidance (nonprecision approach)

MSAS System Architecture



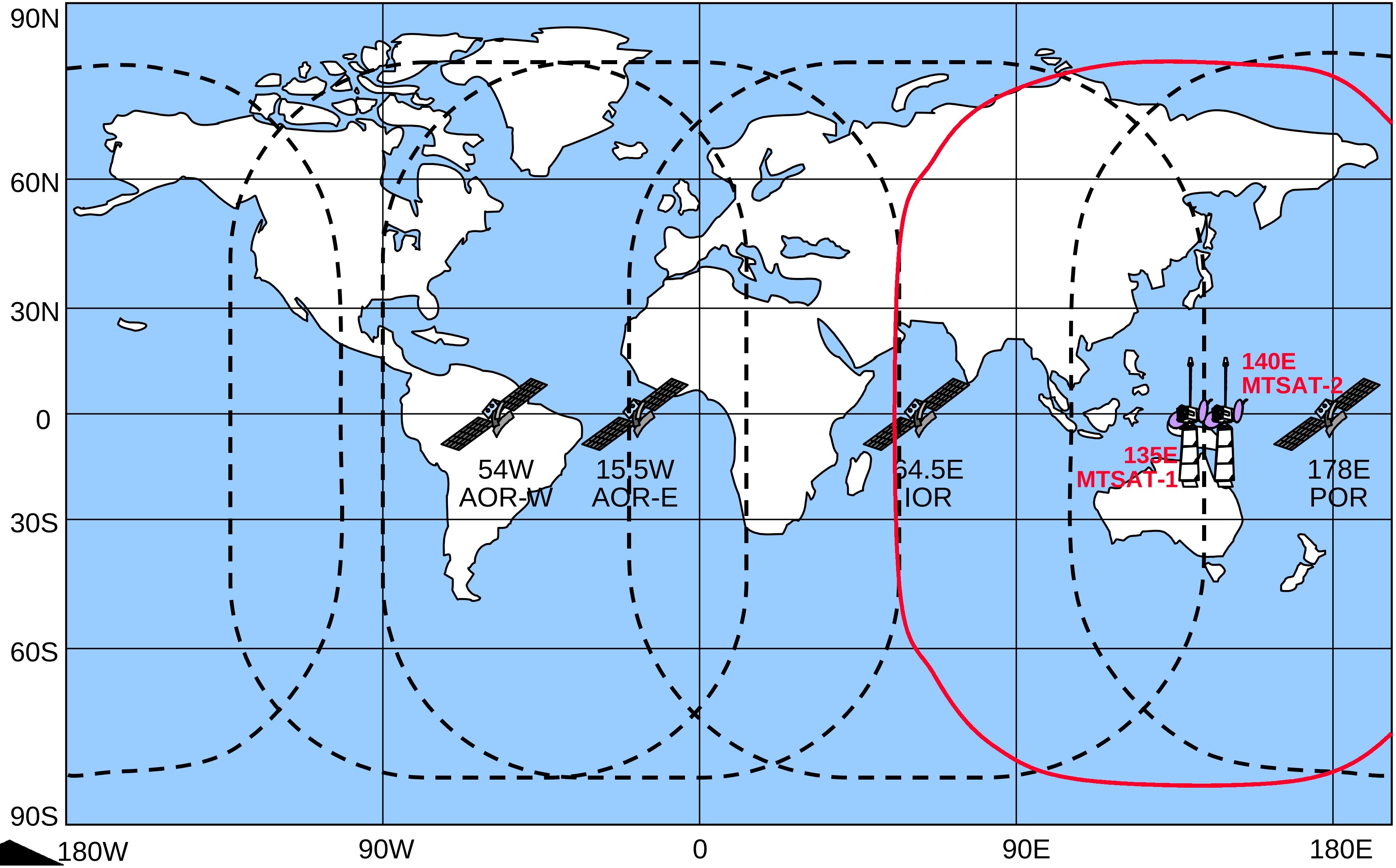
Ground Segment of MSAS

- **GMS (Ground Monitor Station)**
  - Collect data on GPS and SBAS satellite signals and forward to the MCS
  - Screen abnormal received data
- **MRS (Monitor and Ranging Station)**
  - Used mainly for the MTSAT satellite orbit determination
  - Installed in Hawaii and Australia to provide a large baseline
- **MCS (Master Control Station)**
  - Provide system monitor / control
  - Analyze data from monitors and generate differential corrections, MTSAT orbit, and ionospheric delay corrections
  - Judge system integrity
- **NCS (Network Communication System)**
  - Communication system between MSAS subsystems



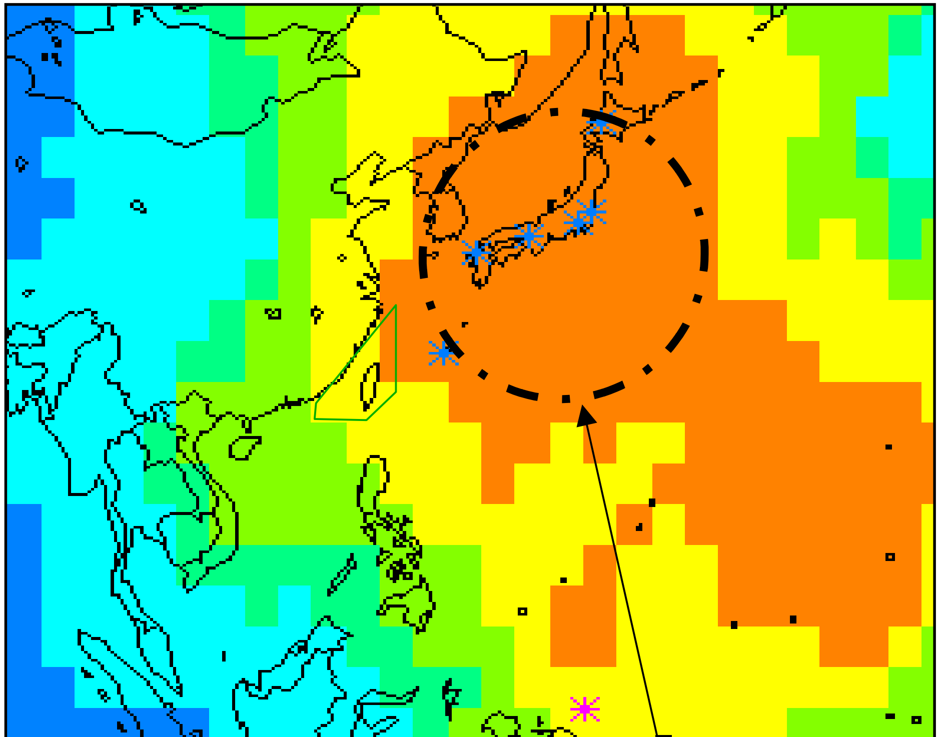
- *MTSAT-1R will be launched in Summer 2003*
- *MTSAT-2 will be launched in Summer 2004*
- *MSAS Phase-1 will be operational in 2005 with MTSAT-1R*
- *MSAS Phase-2 will be operational in 2006 with MTSAT-1R & MTSAT-2*

MTSAT Coverage Footprint

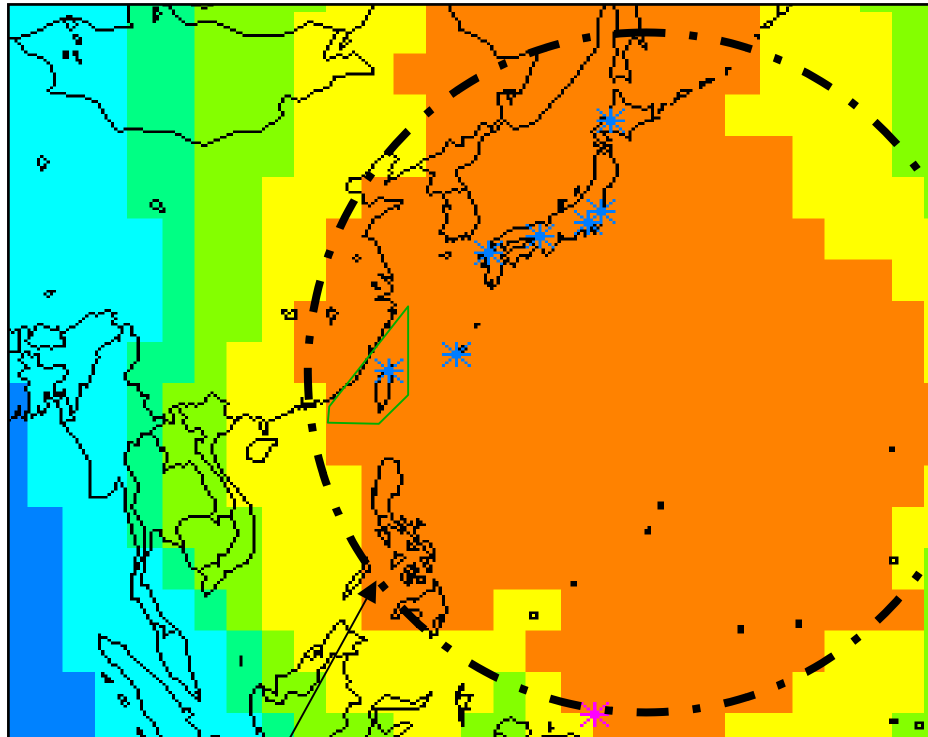


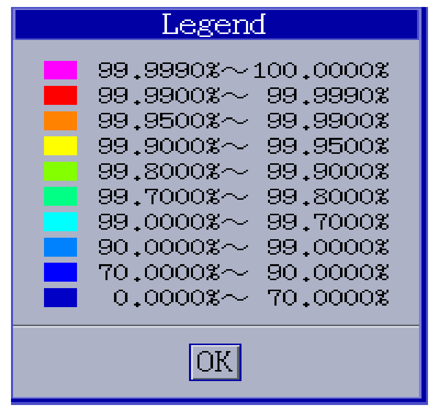
MSAS Simulation of NPA Availability

MSAS 8 Sites



MSAS 8 Sites+Taipei Taiwan





99.95% coverage indicate the effect of additional site

Australia GRAS System

- Master Control Stations [2]
  - ❑Brisbane
  - ❑Melbourne

- Ground Reference Stations [10]
  - Broome
  - Carnavon
  - Perth
  - Darwin
  - Alice Springs
  - Ceduna
  - Thursday Island
  - Mackay
  - Canberra
  - Hobart

- VHF Transmitters
  - o Using current VHF voice site
  - o Connected to Master Stations

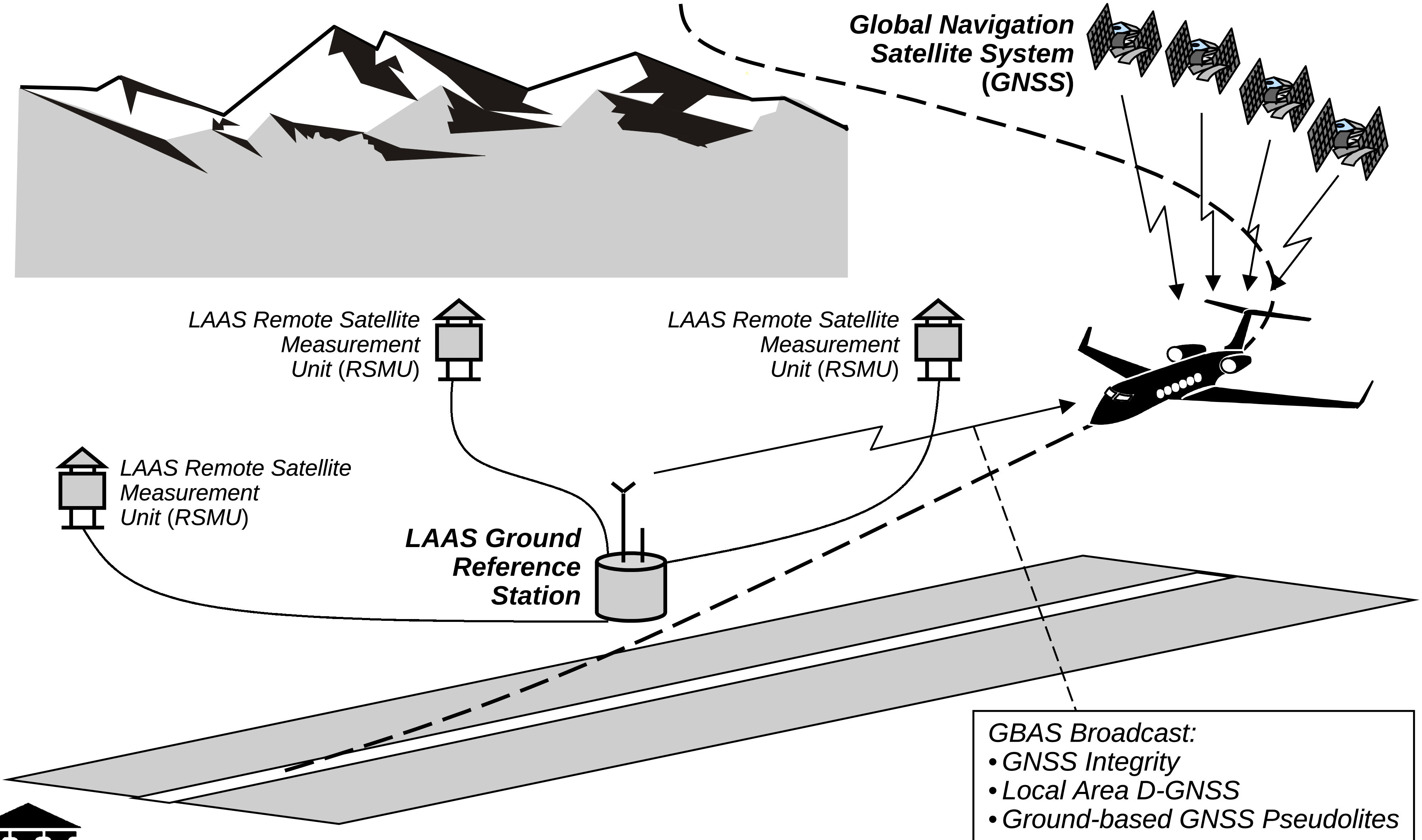
Considerations of Wide-Area Augmentation

- **US WAAS (for performance reference)**
  - \+ Very good overall system accuracy
  - – Need more GEOs to overcome single point-of-failure broadcast link & availability problems (expensive for more GEOs)
  - – Some GNSS satellites observed by aircraft at the boundary of WAAS might not be monitored by WAAS ground reference stations which leads to integrity shortfalls
  - – Integrity for CAT-I landing service is not attainable in current configuration

- **Join Japan MSAS**
  - \+ Expected very good system accuracy
  - \+ No single point of failure in geo-stationary satellite links
  - \+ Lowest implementation cost (expensive cost already paid by Japan)
  - \+ May use the signal for free if neighboring countries already joined MSAS
  - \+ Ground reference stations in neighboring countries provide extra GNSS monitoring
  - – Signal in space controlled by other country (Japan)
  - – Integrity for CAT-I landing service is not attainable in current configuration

- **Build Our Own GRAS as Australia**
  - \+ Expected very good system accuracy
  - \+ In-expensive and no single point of failure ground-based VHF broadcast link
  - \+ Total control of signal in space
  - \+ Signals of ground monitoring stations can be shared with other SBAS or GRAS
  - – Some GNSS satellites observed by aircraft at the boundary of Taipei FIR might not be monitored by GRAS ground reference stations which leads to integrity shortfalls
  - – Integrity for CAT-I landing service is not yet proved to be attainable

Ground Based Augmentation System (GBAS)



Current Taipei FIR Airport Landing Aids

Airport	ICAO	IATA	Landing Aids	Daily Flights*
Taipei CKS International	RCTP	TPE	RWY 05/23: ILS CAT-II, RWY 06/24: ILS CAT-I	330
Kaohsiung International	RCKH	KHH	RWY 09L/27R: ILS CAT-I	246
Taipei Sungshan	RCSS	TSA	RWY 10: ILS CAT-I, RWY 28: LDA	391
Taichung	RCLG	TXG	RWY 36: MLS, NDB	91
Chiayi	RCKU	CYI	RWY 36: ILS CAT-I	43
Tainan	RCNN	TNN	RWY 36R: ILS CAT-I	61
Pingtung South	RCDC	PIF	RWY 09: ILS CAT-I	10
Hualien	RCYU	HUN	RWY 03: MLS, LDA	57
Taitung /Fengnin	RCFN	TTT	RWY 04: MLS, VOR	46
Makung	RCQC	MZG	RWY 02: ILS CAT-I	97
Chimei	RCCM	CMJ	VFR	6
Wang An	RCWA	WOT	VFR	0.6
Chinmen	RCBS	KNH	RWY 06: LDA/DME	51
Matsu	RCMT	MZW	NDB	11
Green Island	RCGI	GNI	VFR	11.4
Lanyu	RCLY	KYD	VFR	8.2

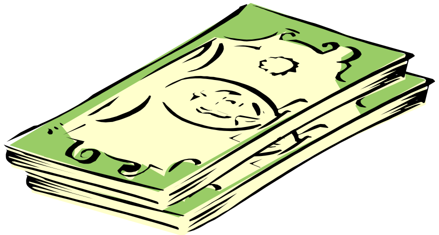
*Data Source : Monthly Statistics Report, ROC CAA, January 2002

GNSS Evaluation System

- Setup a evaluation system to determine the necessity and architecture of GNSS augmentation in Taipei FIR:
  - Collects GPS data in critical areas such as airports, airway fixes, FIR route boundaries.
  - Establish GNSS analysis model and evaluate the GNSS accuracy, availability, integrity, and continuity of service for all candidates of augmentation architecture for Taipei FIR including:
    - SBAS with MSAS program plus GBAS
    - Our own GRAS plus GBAS
    - GBAS only
  - Include all share holders (government policy makers, CAA, airlines) to determine the best GNSS augmentation architecture for Taipei FIR
  - Define implementation plan, technical specifications, and associated regulations and procedures for the selected augmentation systems
- Based-on the recommendation of the above analysis, implement our own GRAS or work with Japan MSAS (MTSAT Satellite-based Augmentation System) to implement SBAS for en-route and terminal GNSS navigation.
- For precision landing aid, Implement GBAS CAT-I/II in Taipei CKS airport first, and to other airports if analysis shows necessary.

Surveillance

Limitations in Current Radar Surveillance

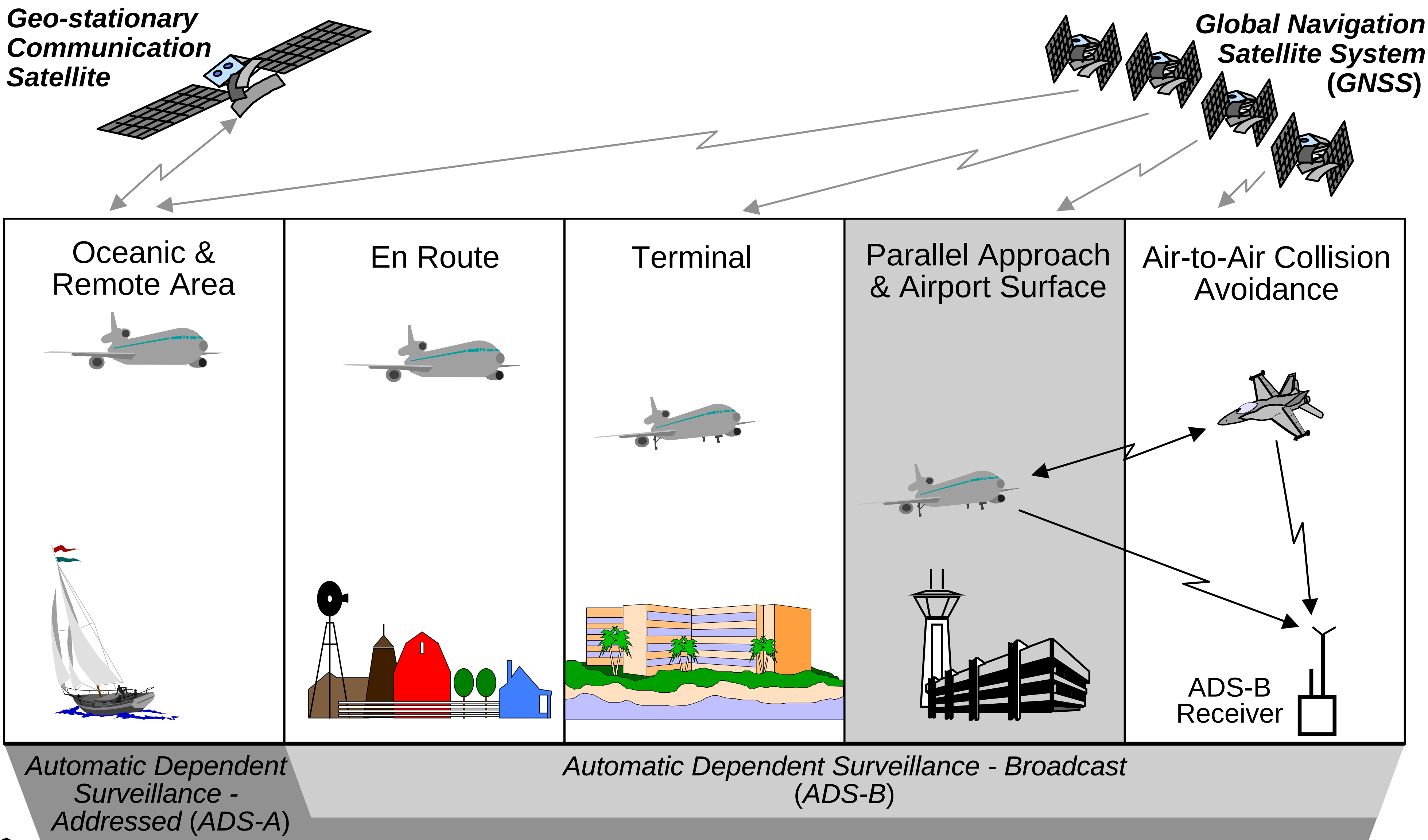


- Line-of-sight limitation on radar surveillance coverage
- Lack of air-to-air situation awareness
- Radar is expensive to purchase, operate and maintain

Transitions of Surveillance Systems

Phase of Flight	Current Surveillance Systems	CNS/ATM Surveillance Systems
En-Route Oceanic	• HF Voice Position Report in every 45~60 minutes	• ADS-A: Automatic Dependent Surveillance – Addressed
En-Route Domestic	• ARSR: Air Route Surveillance Radar • MSSR: Monopulse Secondary Surveillance Radar	• ADS-B: Automatic Dependent Surveillance – Broadcast
Terminal	• ASR: Airport Surveillance Radar • MSSR: Monopulse Secondary Surveillance Radar	
Take-Off & Landing	• ASDE: Airport Surface Detection Equipment • MDS: Multi-static Dependent Surveillance	
Airport Surface		

Final Goal of Surveillance in CNS/ATM

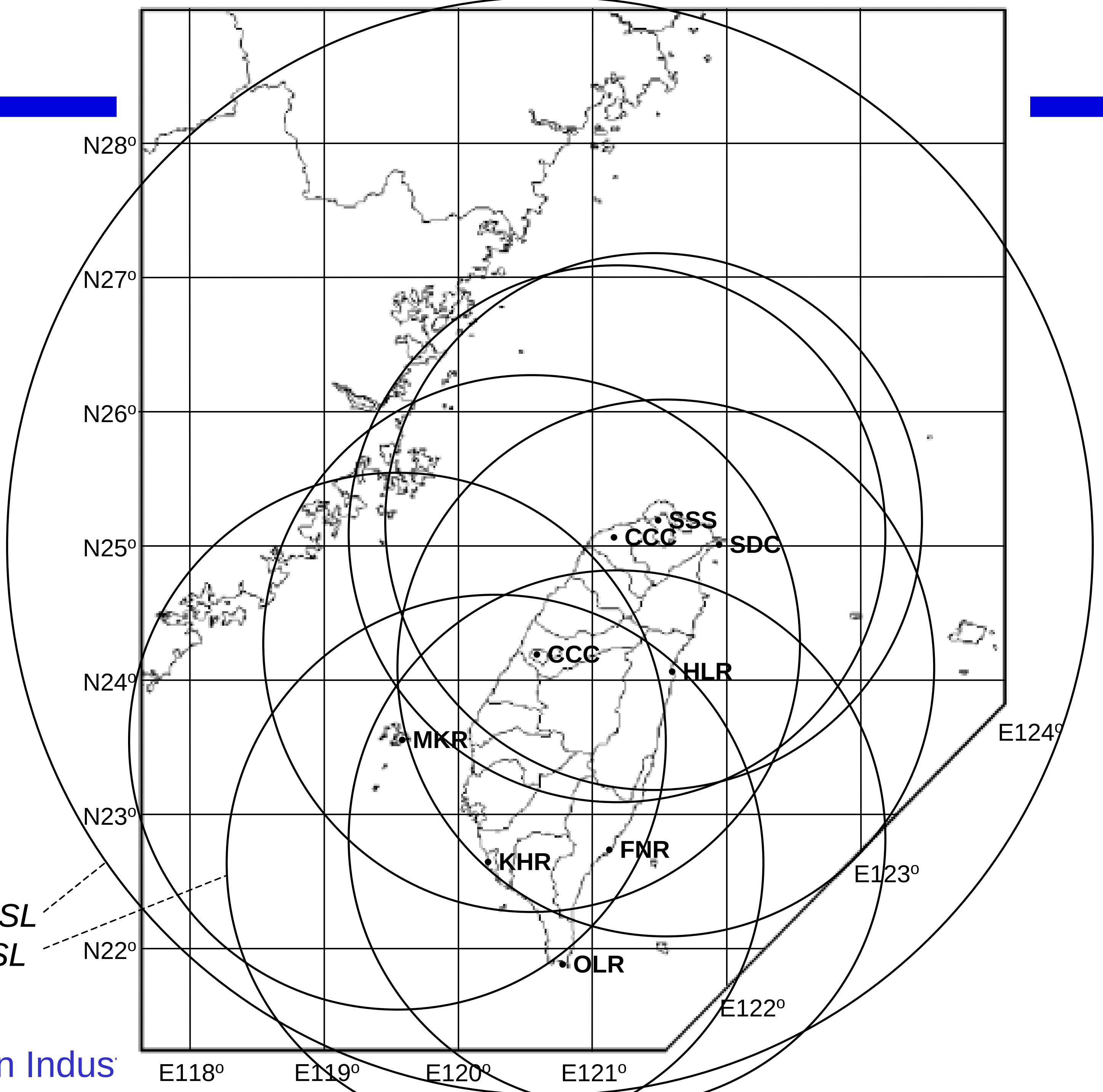


Implementation Strategy - Surveillance

- **Radar Surveillance:**
  - Very good en-route and terminal primary and secondary radar surveillance coverage throughout Taipei FIR.
  - Implement combined ASDE/multi-static dependent surveillance (MDS) system for CKS airport surface surveillance, and other airport if necessary.

- **ADS Surveillance:**
  - To provide infrastructure for future FANS routes for Taipei FIR, implement ADS and CPDLC over existing air-ground data link or future on ATN according to ICAO and neighboring FIR's schedule.
    - Due to the very low reporting rate (> every 5 min) and long transmission delays (5-6 sec for VDL and 1 min for SatCom), the ADS is only good for oceanic surveillance. For Taipei FIR containing no oceanic airspace, the ADS can only use as a reference for the radar/ADS-B based surveillance infrastructure.
  - ADS-B will be the next generation transponder technology for en-route, terminal, airport surface surveillance, as well as air-to-air situation awareness. Follow closely the progresses of international ADS-B standards.
  - Implement multi-sensor data fusion surveillance including PSR, SSR, ADS, ADS-B types of sensors in the upgrade of ATM system.

Current Taipei FIR Radar Coverage



- *En-Route SSR at 30,000ft MSL*
- *Terminal SSR at 10,000ft MSL*

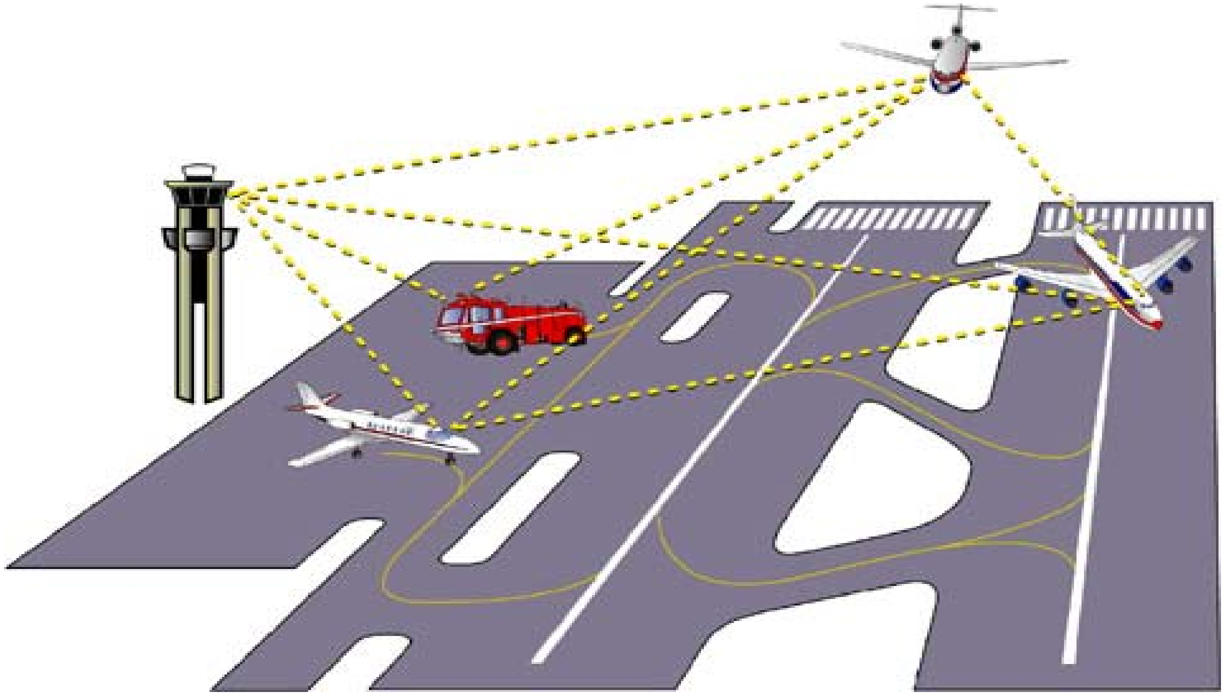
Current Taipei FIR Radars

	Radar Name	ID	Commission Date	Specifications
En-Route Surveillance Radar	San-Tiao-Chiao En-Route Radar *(Raytheon ASR-23SS)*	SDC	2001	• PSR: L-band, 5 rpm, 220NM Range • MSSR: S-band, 250NM Range, Mode-A/C
	Oluanpi En-Route Radar *(Raytheon ASR-23SS)*	OLR	2001	• PSR: L-band, 5 rpm, 220NM Range • MSSR: S-band, 250NM Range, Mode-A/C
	Makung Mid-Range Radar *(Thales TRAC-2100)*	MKR	1990	• PSR: L-band, 13 rpm, 90nmi Range • MSSR: S-band, 180nmi Range, Mode-A/C
Terminal Surveillance Radar	Taipei CKS Terminal Radar *(Northrop Grumman ASR-9)*	CCC	1994	• PSR: S-band, 13 rpm, 60nmi Range • MSSR: S-band, 180nmi Range, Mode-A/C
	Taichung Terminal Radar *(Northrop Grumman ASR-9)*	TTR	1994	• PSR: S-band, 13 rpm, 60nmi Range • MSSR: S-band, 180nmi Range, Mode-A/C
	Kaohsiung Terminal Radar *(Northrop Grumman ASR-9)*	KHR	1994	• PSR: S-band, 13 rpm, 60nmi Range • MSSR: S-band, 180nmi Range, Mode-A/C
	Taipei Sungshan Terminal Radar *(ITT ARGOS-73)*	SSS	2000	• PSR: S-band, 13 rpm, 60nmi Range • MSSR: S-band, 180nmi Range, Mode-A/C
	Hualien Terminal Radar *(ITT ARGOS-73)*	HLR	2000	• PSR: S-band, 13 rpm, 60nmi Range • MSSR: S-band, 180nmi Range, Mode-A/C
	Taitung Terminal Radar *(ITT ARGOS-73)*	FNR	2000	• PSR: S-band, 13 rpm, 60nmi Range • MSSR: S-band, 180nmi Range, Mode-A/C

Airport Surface Detection Equipment (ASDE)

System Description:

1. A primary surveillance radar (PSR) for airport surface detection normally being called as Surface Movement Radar (SMR) or Airport Surface Detection Equipment (ASDE)
2. Operates in the X or Ku band (9-18GHz) with a range of 4+ NM



Attributes:

1. Provides range and azimuth information of all targets within the radar coverage at a nominal one second (1Hz) update rate
2. Does not dependent on avionics or equipment carried on the target

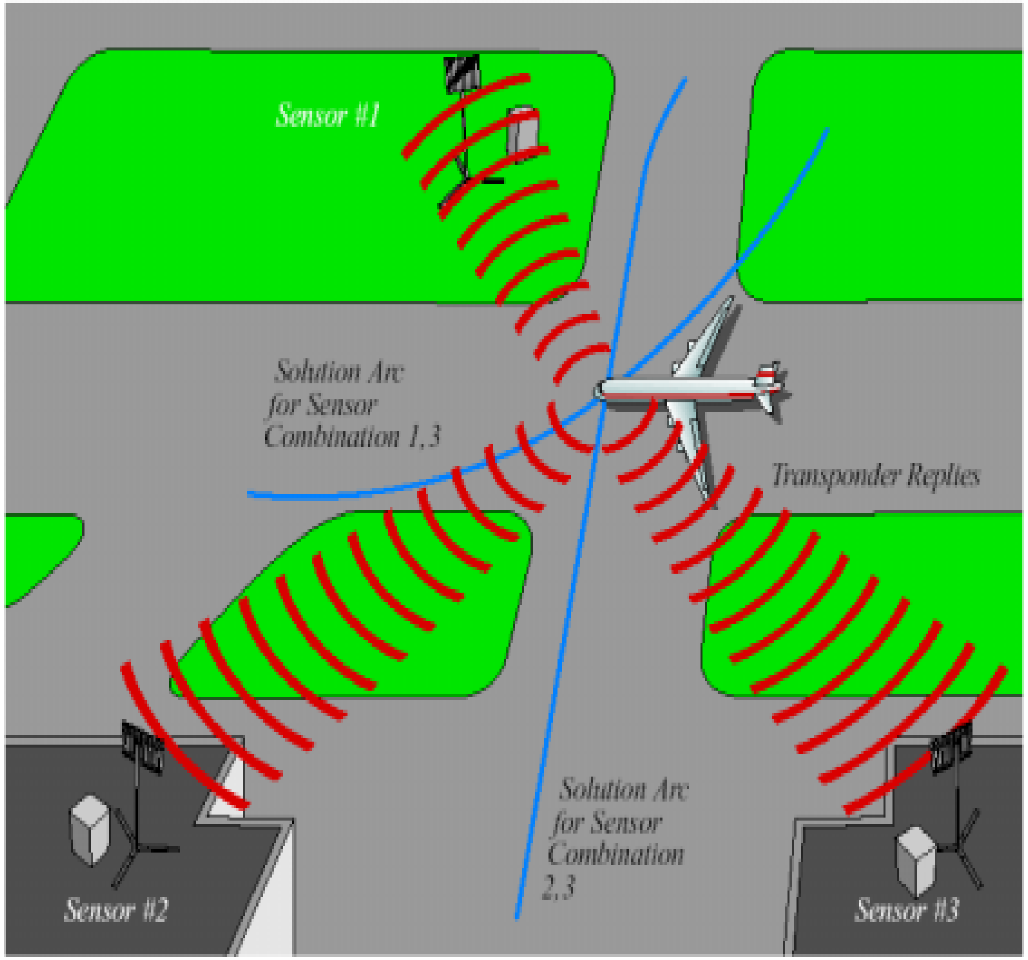
Limitations:

1. Does not provide positive target identification
2. Single sensor 'line-of-sight' coverage limitations
3. Expensive to operate and maintain
4. Poor performance in bad weather (heavy rain)
5. Prone to multipath and false target problems

Multistatic Dependent Surveillance (MDS)

System Description:

1. A multi-sensor secondary surveillance system that utilizes aircraft Mode A/C and Mode S transponder equipment
2. Operates on 1030/1090 MHz with a range out to 10 NM



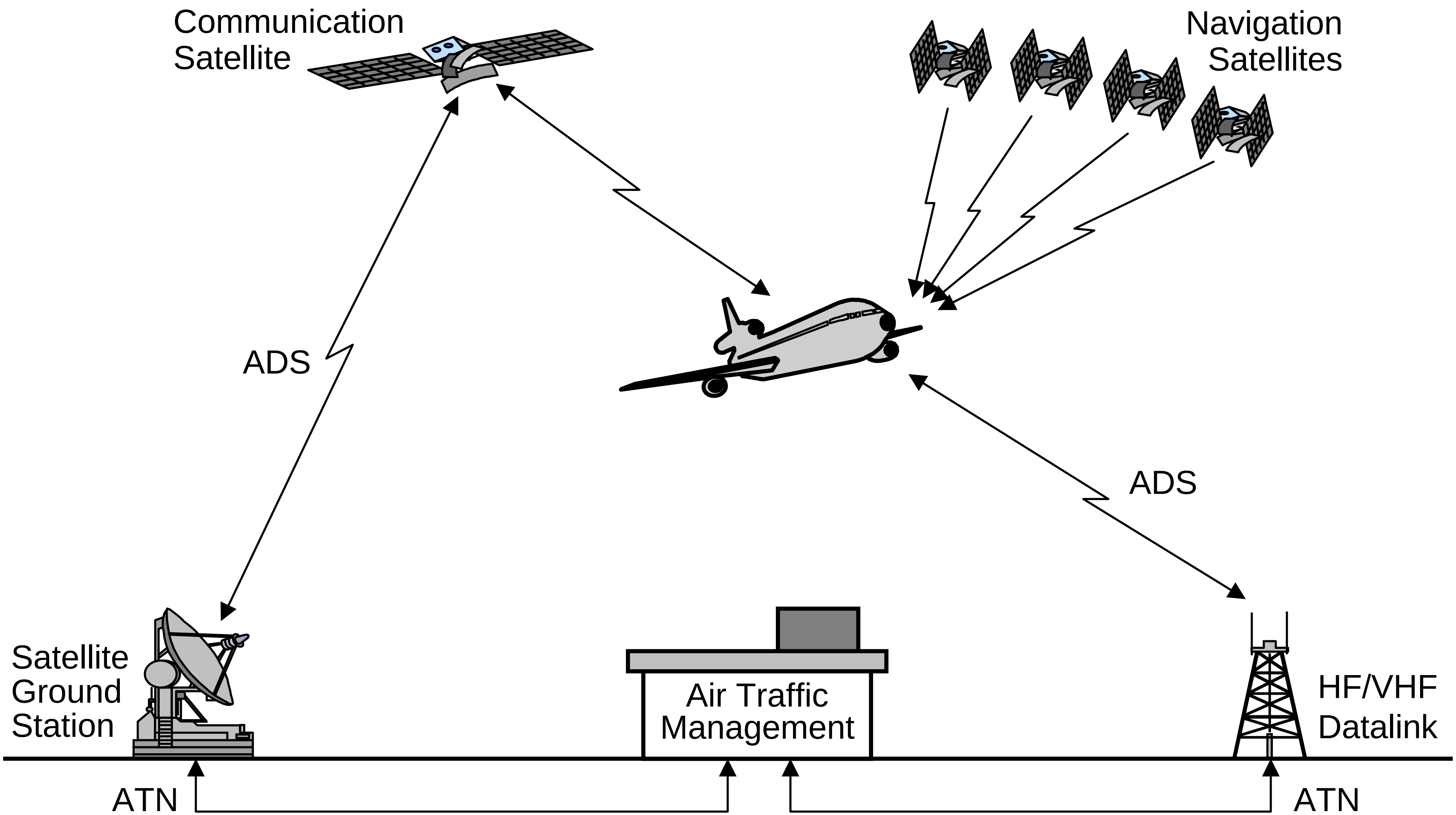
Attributes:

1. All-weather, high accuracy, high update rate surveillance of all targets
2. Electronic scan fixed antenna with an adaptable update rate from 1 to 10 Hz
3. Provides positive identification for all transponder-equipped aircrafts/vehicles
4. Not suffer from 'line-of-sight' coverage limitations using multiple remote units
5. Relatively low cost to purchase, operate and maintain compare to ASDE
6. Expand coverage 'as & when' required

Limitations:

1. Reliant on aircraft/vehicle on-board transponder equipment

Automatic Dependent Surveillance (ADS)

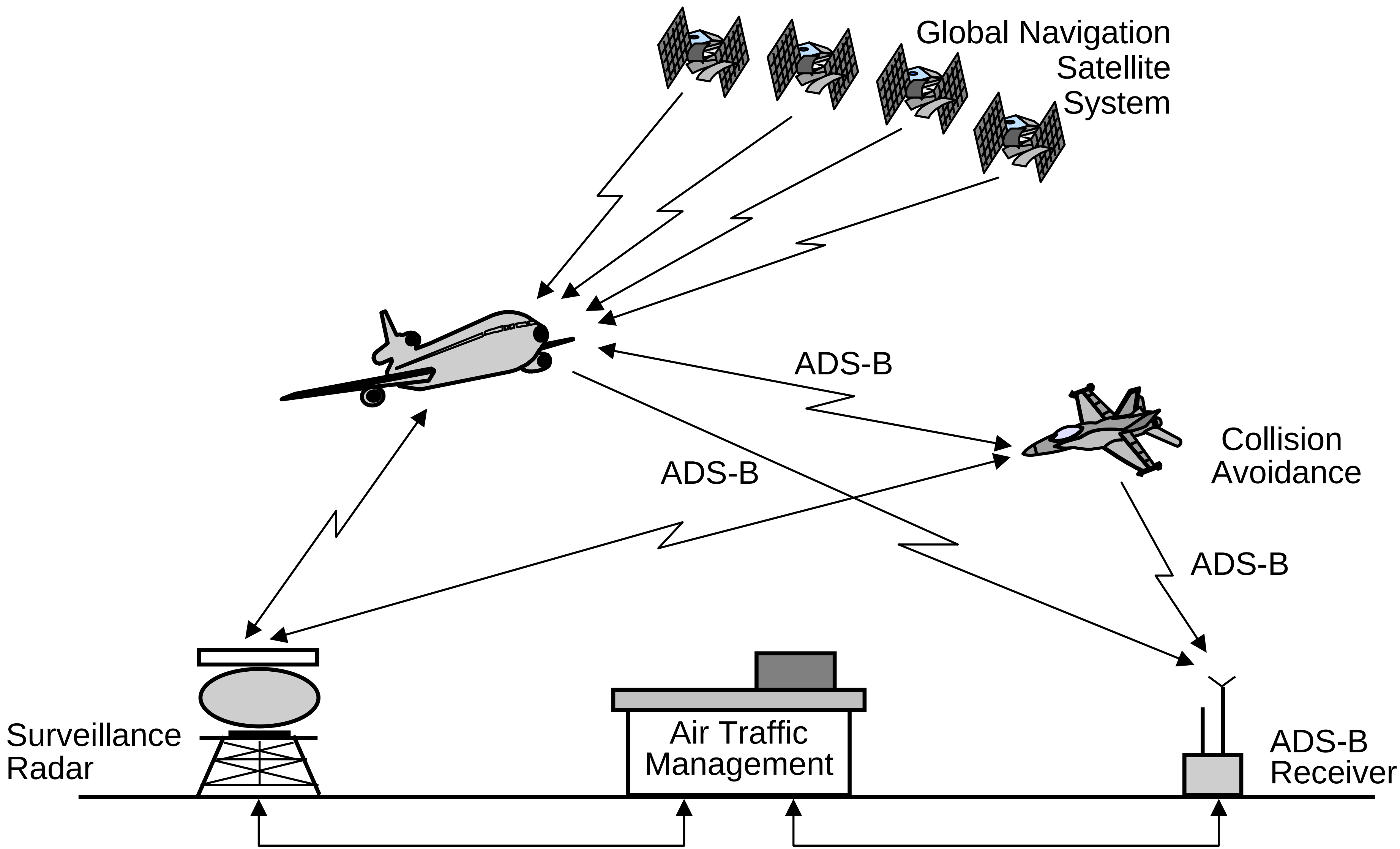


ADS Functional Specifications

- **ADS Report Medium & Rate**
  - Report through ATN
  - Every 64 sec or longer in FANS-1
- **Types of Contacts**
  - Periodic Contract
  - Event Contract
  - Demand Contract
- **Basic ADS Messages**
  - *Basic ADS Report*
    - Latitude/longitude
    - Altitude
    - Time
    - Figure of merit
    - Field activation/ADS capability
    - Flight identification

- **Extended & Associated ADS Messages**
  - *Extended ADS Report*
    - Next way-point
    - Estimated altitude at next way-point
    - Next+1 way-point
    - Estimated altitude at next+1 way-point
    - Tracking/heading
    - IAS/Mach
    - Vertical rate
  - *Associated ADS Report*
    - Wind speed
    - Wind direction
    - Temperature

Automatic Dependent Surveillance-Broadcast (ADS-B)



ADS-B Functional Specifications

- **ADS-B Data Link Standard**
  - Mode-S Extended Squitter, @1090MHz
  - VDL Mode-4, @118-137MHz
  - Universal Access Transceiver (UAT), @ 978MHz

- **ADS-B Broadcast Rate**
  - Every 1-30 sec
  - Depends on application

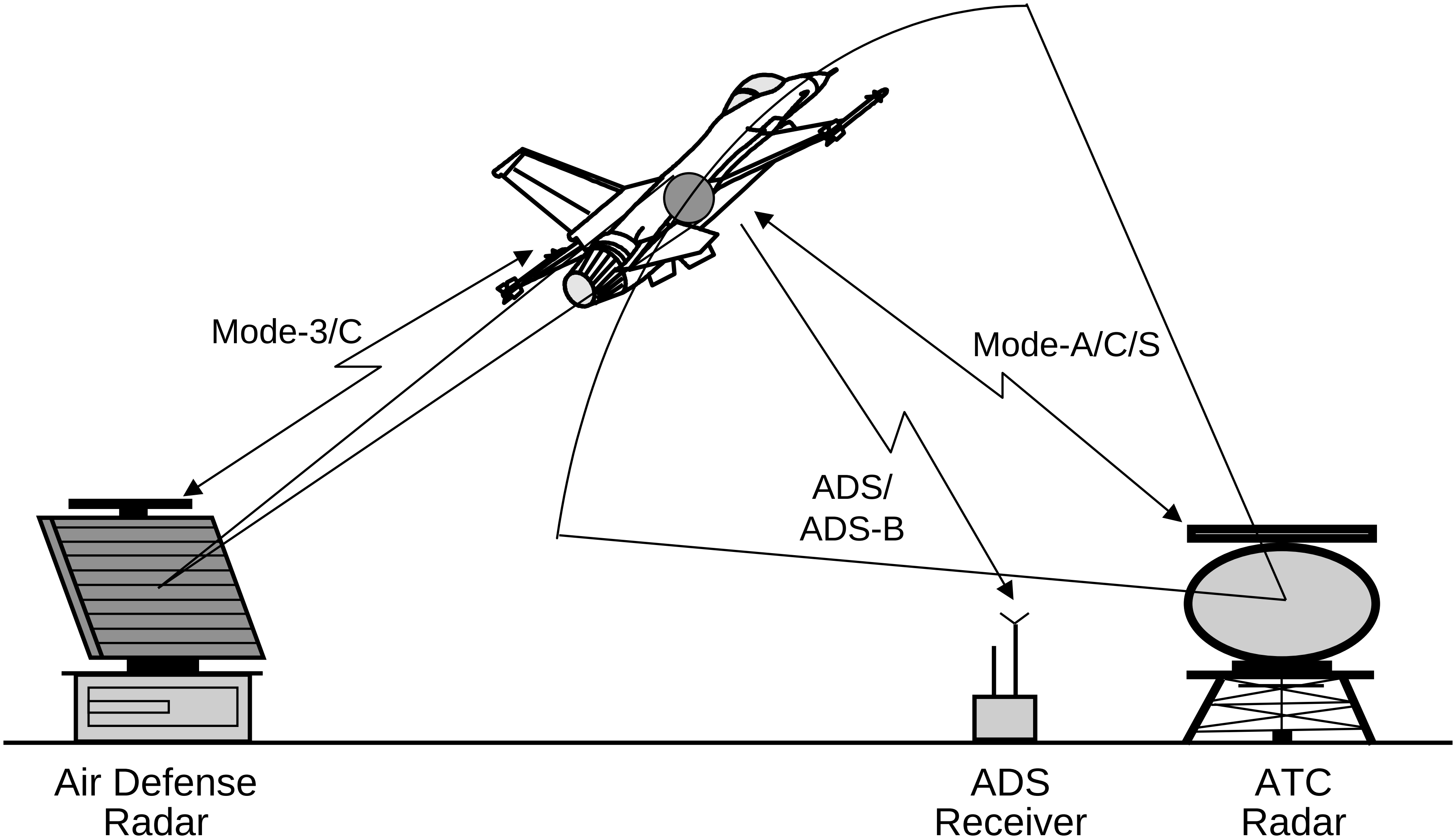
- **ADS-B Message Format**
  - *Identification*
    - Call sign
    - Address
    - Category

- **ADS-B Message Format (conti)**
  - *Position Vector*
    - Latitude/longitude
    - Barometric altitude
    - Geometric height
    - Source of altitude
    - Position uncertainty category
  - *Velocity Vector*
    - Horizontal velocity vector
    - Vertical rate
    - Velocity uncertainty category
  - *Tactical Parameters*
    - Trajectory change point
    - Target altitude
    - Turn rate
    - Emergency/priority status

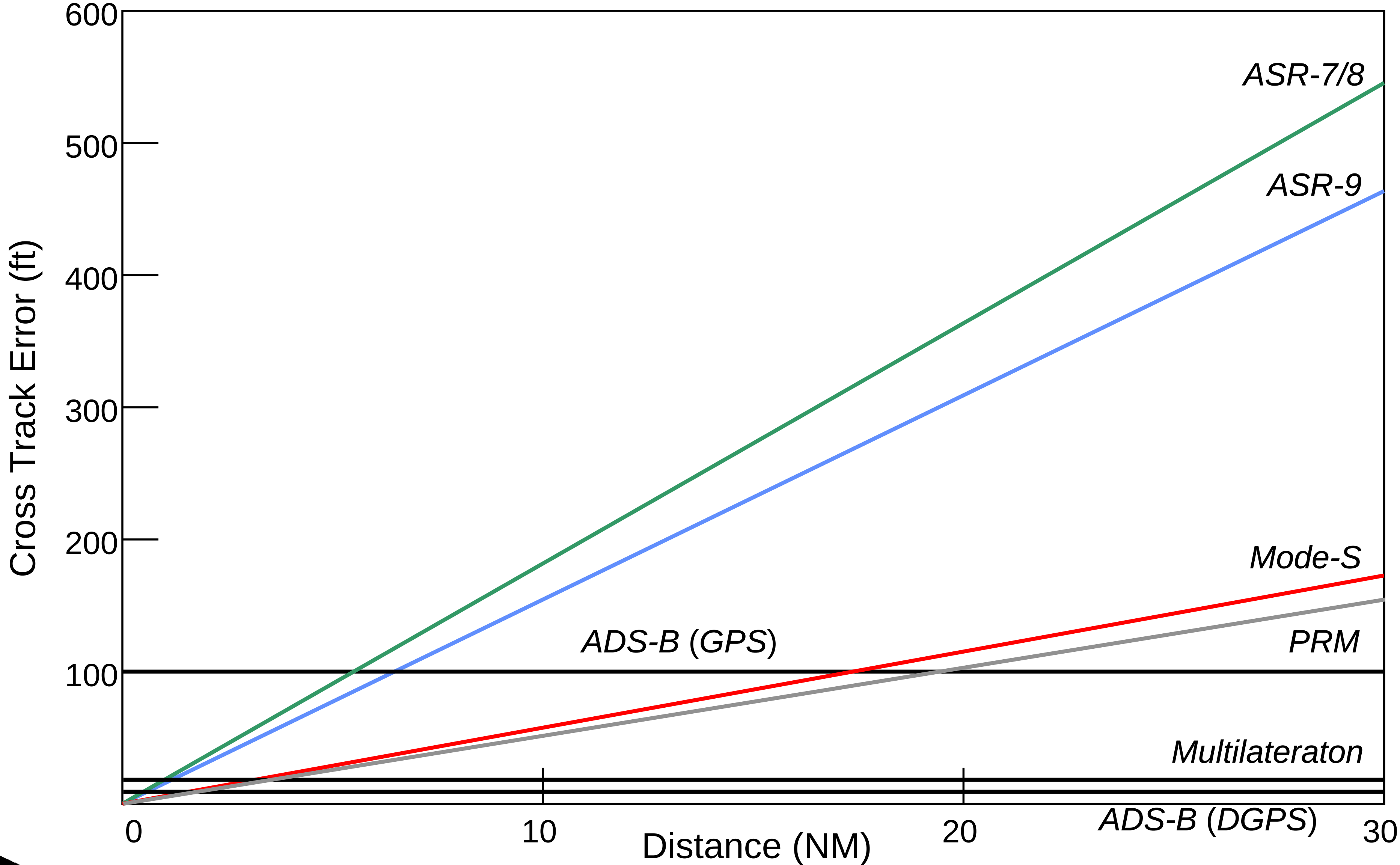
ADS Performance Requirement

	Oceanic/ Remote Area	En-Route	Terminal	Airport Surface	Parallel Approach	Collision Avoidance
Operational System	ADS-A	ADS-B	ADS-B	ADS-B	ADS-B	ADS-B
Data Link Medium	ATN	TBD	TBD	TBD	TBD	TBD
2-Way Comm	Yes	No	No	No	No	No
Update Period	64 sec/Min 305sec/Ave	12 sec	5 sec	1 sec/motion 30sec/station	1 sec	2.5 sec
Operational Range	Unlimited	200 NM	60 NM	5 NM	30 NM	30 NM
Horizontal Position Error	350 m	350 m	150 m	3 m	9 m	40 m
Altitude Error	30 m	30 m	30 m	18 m	30 m	7.5 m
Horizontal Velocity Error	10 knots	10 knots	5 knots	1 knots	10 knots	0.6 m/s
Vertical Rate Error	0.61 m/s	0.61 m/s	0.61 m/s	0.61 m/s	0.61 m/s	0.61 m/s

Multi-Sensor Fusion Surveillance



Sensor Accuracy Comparison



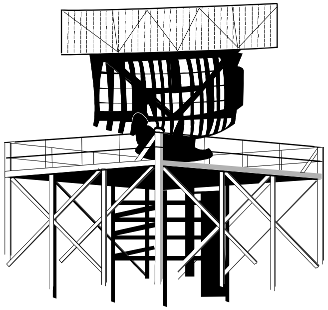
Surveillance Sensor Characteristics

Sensor Source	Update Rate	Coordination	Message Contents
Primary Surveillance Radar (PSR)	Every 4.5~12 sec	Radar Polar Coordinate	• Time • Azimuth • Range
Secondary Surveillance Radar (SSR)	Every 4.5~12 sec	Radar Polar Coordinate	• Aircraft Beacon Code • Time • Azimuth • Range • Altitude
ADS	Averaged every 10 min (64 sec - 45 min)	WGS-84	• Aircraft ID • Call Sign • Time • Latitude/Longitude/Altitude • Velocity (Optional) • Way-Point (Optional)
ADS-B & Military GPS	1~10 Hertz	WGS-84	• Aircraft ID • Call Sign • Time • Latitude/Longitude/Altitude • Horizontal/Vertical Velocity

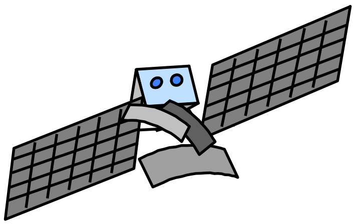
Sensor and Associated ATS Services

Sensor Source	Separation Service	FDP Service	Data Link Services
Search Radar (PSR)	• No separation service	No	No
Beacon Radar (SSR)	• 3-mile separation for terminal single radar coverage • 5-mile separation for en-route multiple radar mosaic coverage	Yes	No
ADS (Automatic Dependent Surveillance)	• 50-mile separation	Yes	• Controller-Pilot Data Link Communication (CPDLC) • Pre-Departure Clearance (PDC) • Digital Automatic Traffic Information Service (D-ATIS)
ADS-B (Automatic Dependent Surveillance-Broadcast)	• 3-mile separation	Yes	No

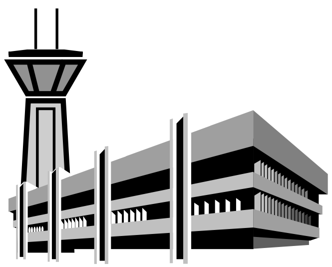
Considerations in Surveillance Processing



PSR & SSR



GPS & ADS-B



ADS & IFDT

Input Data Processing → **Tracking Processing** → **Surveillance Data Presentation**

Input Data Processing

Wide Range of Surveillance Sources:

- Different Sensor Accuracy
- Different Sensor Update Rates
- Different Data Contents & Formats
- Different Coordination Systems
- Surveillance Mosaic Scheme

Tracking Processing

Tracking Problems Due to Different Sensor Characteristics:

- Target/Track Correlation
- Assignment Processing
- Track Initiation & Establishment
- Track Update & Prediction
- Track Coast & Termination

Surveillance Data Presentation

Different Operation Requirements for Data Presentation:

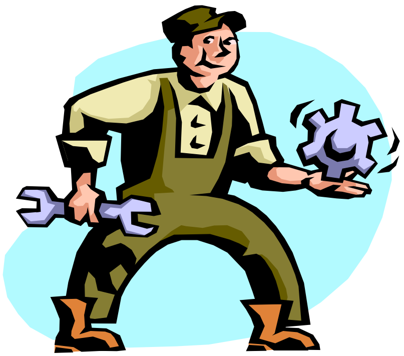
- Terminal ATC Operation
- En-Route ATC Operation
- Oceanic ATC Operation
- Military ATC Operation
- System Emergency Operation

Air Traffic Management

Limitations in Current ATC

- Lack of Integration with New Generation CNS Infrastructure

- Need Improvement in Safety Monitoring



- Lack of Automation Tools to Optimize Resource Utilization

Transitions of Air Traffic Management

Functions	Current ATC System (Lockheed Martin NAS & EARTS)	ATM System
System Architecture	• Hardware: Proprietary computer, display subsystem, I/O subsystems • Software: Proprietary operating system, window system, communication protocols	• Commercial-off-the shelf (COTS) hardware & subsystems • Open software and protocol standards (UNIX, X-Win, C, TCP, UDP/IP)
Surveillance Data Processing	• Terminal: Single or multi-radar surveillance • En-Route: Multiple-radar 2D mosaic sur. • Tracking: Single-mode Alpha-Beta filter tracking to controlled targets (w/ FP) only	• 3D Mosaic multiple-sensor (radar, ADS-B, ADS) data fusion surveillance • Multi-mode Kalman filter tracking • On-line selectable SDP data presentation
Flight Data Processing	• Flight data processing (FDP)	• Flight data processing (FDP) • Integrated CPDLC • Integrated PDC • Integrated AIDC
Safety Processing	• Minimum safe altitude warning (MSAW) • RDP-based conflict alert (CA) • Airspace Protection (AP)	• Minimum Safe Altitude Warning (MSAW) • Conflict Alert (CA) • Airspace Protection (AP) • Conflict Probe (CP)
Air Traffic Management	• N/A	• Air Space Management (ASM) • Air Traffic Flow Management (ATFM)

Implementation Strategy - ATM

- **Taipei FIR Airspace:**
  - Review and reorganize Taipei FIR's airspace, air routes, ATC sector plan and associated procedures based on the new generation of CNS infrastructure to facilitate the optimum use of airspace.

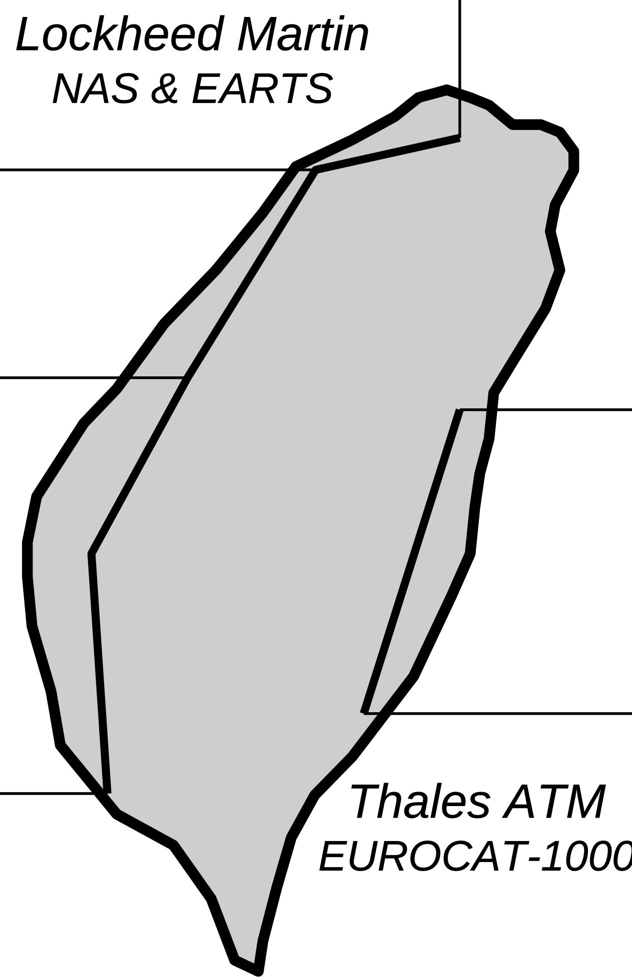
- **ATM Facilities & Systems:**
  - Consolidate 6 current ATC centers into 1 ~3 ATM centers to facilitate the management & utilization of manpower and facilities.
  - Replace the current ATC systems with a new ATM system which should have the following functions:
    - Open software and hardware architecture.
    - Integrated Surveillance Data Processing (SDP) capability for radar, ADS-B, and ADS.
    - Flight Data Processing (FDP) integrated with Conflict Probe (CP) and data link applications such as CPDLC, PDC and AIDC.
    - Air Traffic Flow Management (ATFM) functions for domestic flights.
  - Taipei FIR has a very straight forward route structure and permanent airspace assignment, but its operation is complex. Some proposed ATM functions such as flexible use of airspace (FUA) or terminal flow management (CTAS) will have very limited benefits to improve air traffic operations.

Current Taipei FIR ATC Centers

Taipei (CKS) TCC
- Sungshan West
- CKS
- Taoyang
- Hsinchu
- Sungshan East
- Training

Taichung (TCG) TCC
- Taichung Overflight
- Taichung
- Chiayi Overflight
- Chiayi
- Training

Kaohsiung (KHH) TCC
- Kaohsiung Overflight
- Tainan
- Kangshan
- Kaohsiung
- Training

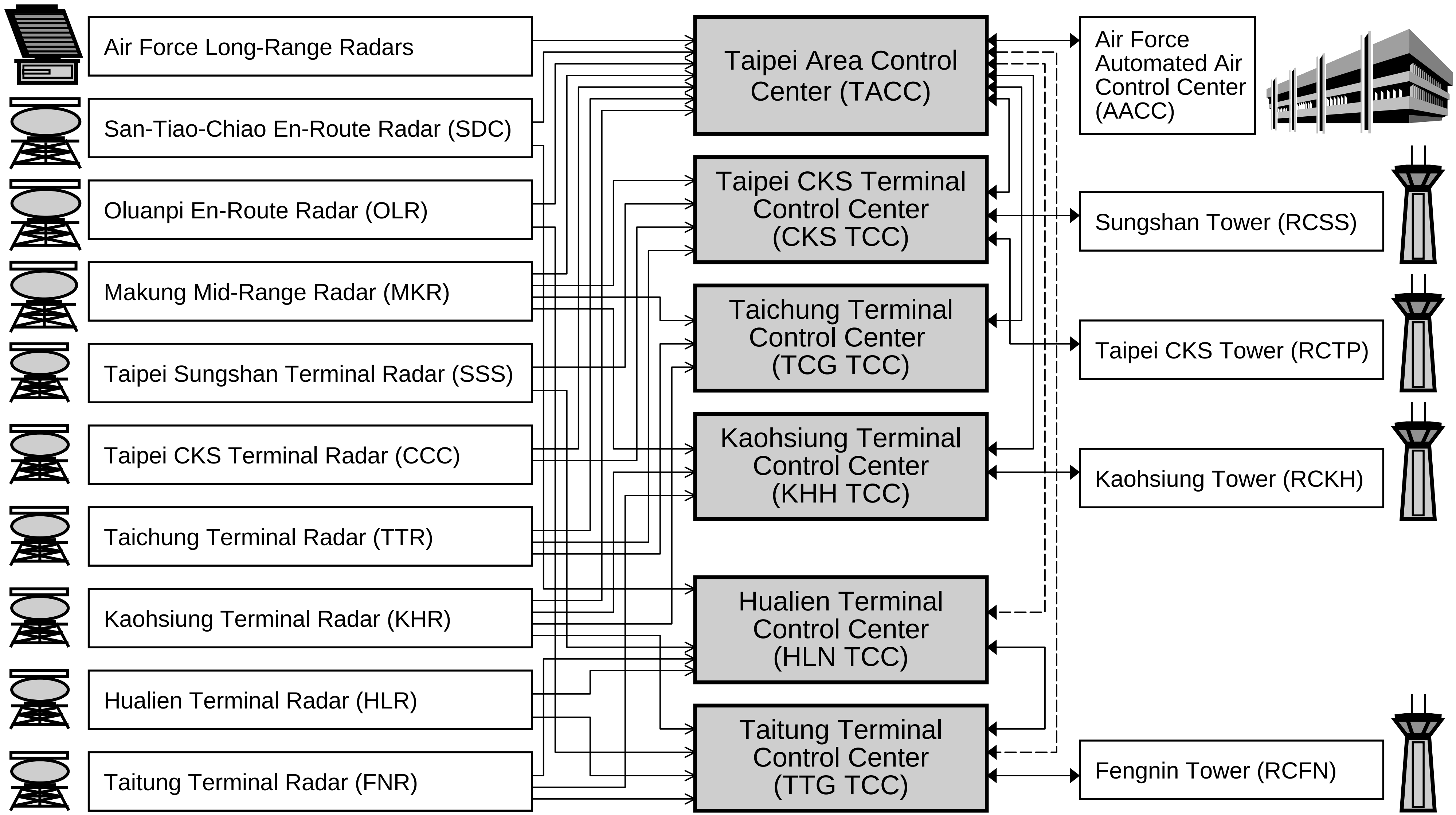


Taipei ACC (TACC)
- Taipei Control North
- Taipei Control West
- Taipei Control South
- Taipei Control East
- Chinmen
- Makung
- Training 1
- Training 2

Hualien (HLN) TCC
- Hualien Civil
- Hualien Military

Taitung (TTG) TCC
- Taitung Fengnin
- Taitung Chihhong

Current Taipei FIR ATC System



Radar Line
IFDT (Inter-Facility Data Transfer) Line
Remote Terminal Line

Airspace Management in Taipei FIR

- **Airspace Management (ASM):**

  Airspace Management involves the design, organization, and use of route network, airspace structure, and air traffic management procedures to facilitate the optimum use of airspace.

- **Taipei FIR Airspace:**

  Review and redesign the following Taipei FIR's airspace components based on the new generation of CNS infrastructure:
  - Airspace classes
  - Air routes and departure/arrival procedures
    - Route structure
    - Standard Instrument Departure (SID)
    - Standard Terminal Arrival Routes (STAR)
    - Instrument Arrival Procedures (IAP)
  - ATC Sector plans

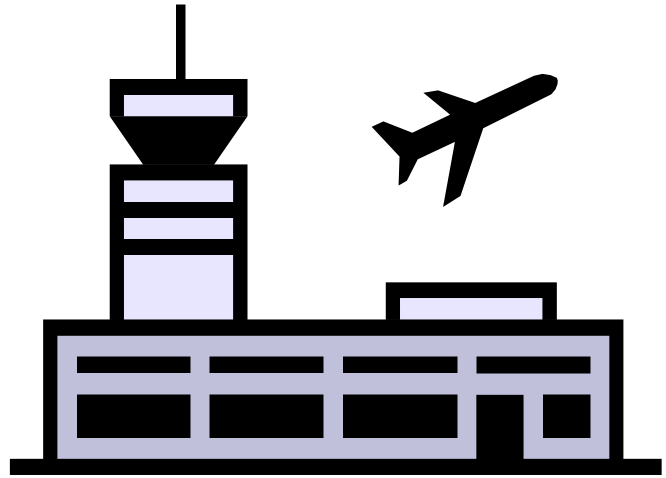
- **Implementation of ATM System:**

  Implement the new ATM system based on the projected air traffic demands, ATS operational requirements and the new airspace structure in Taipei FIR.

Consolidated New ATM Center

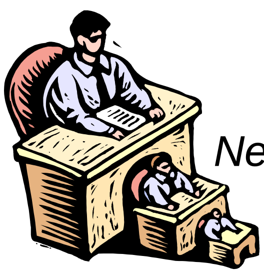
The consolidated 6 current ATC centers into 1~3 ATM centers, each should have enough space and power capacity for:

- Administration
- Controller consoles for whole Taipei FIR operation
- All ATS equipments
- Maintenance personnel & lab equipments
- Training facilities
- Space for next-generation ATM operation transitions



Administration

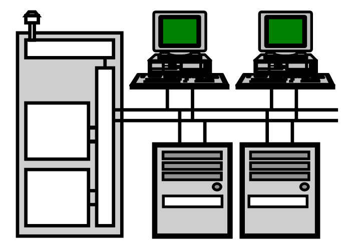
ATS Operation



Space for Next-Generation ATM System Transition

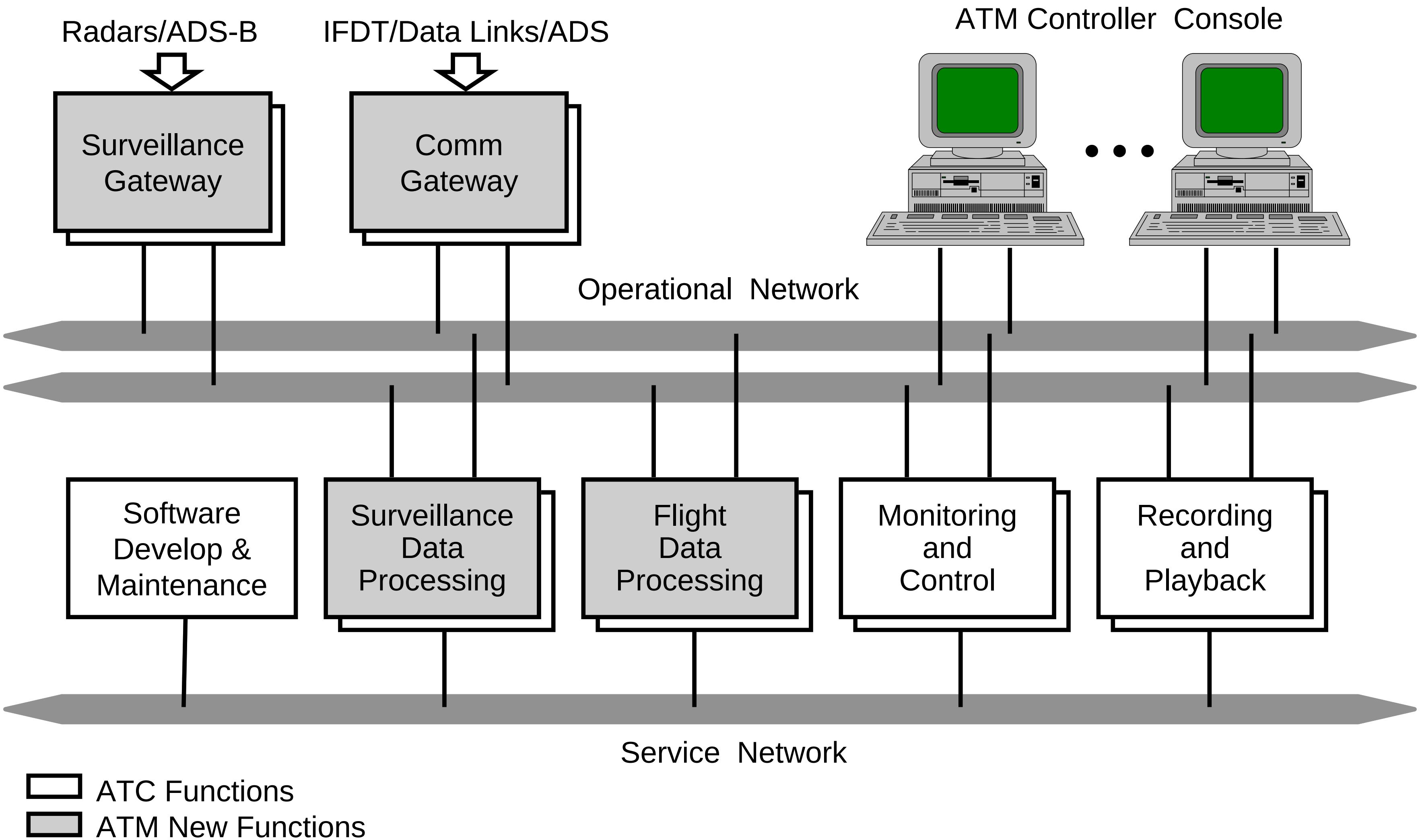
Training Facility

Maintenance

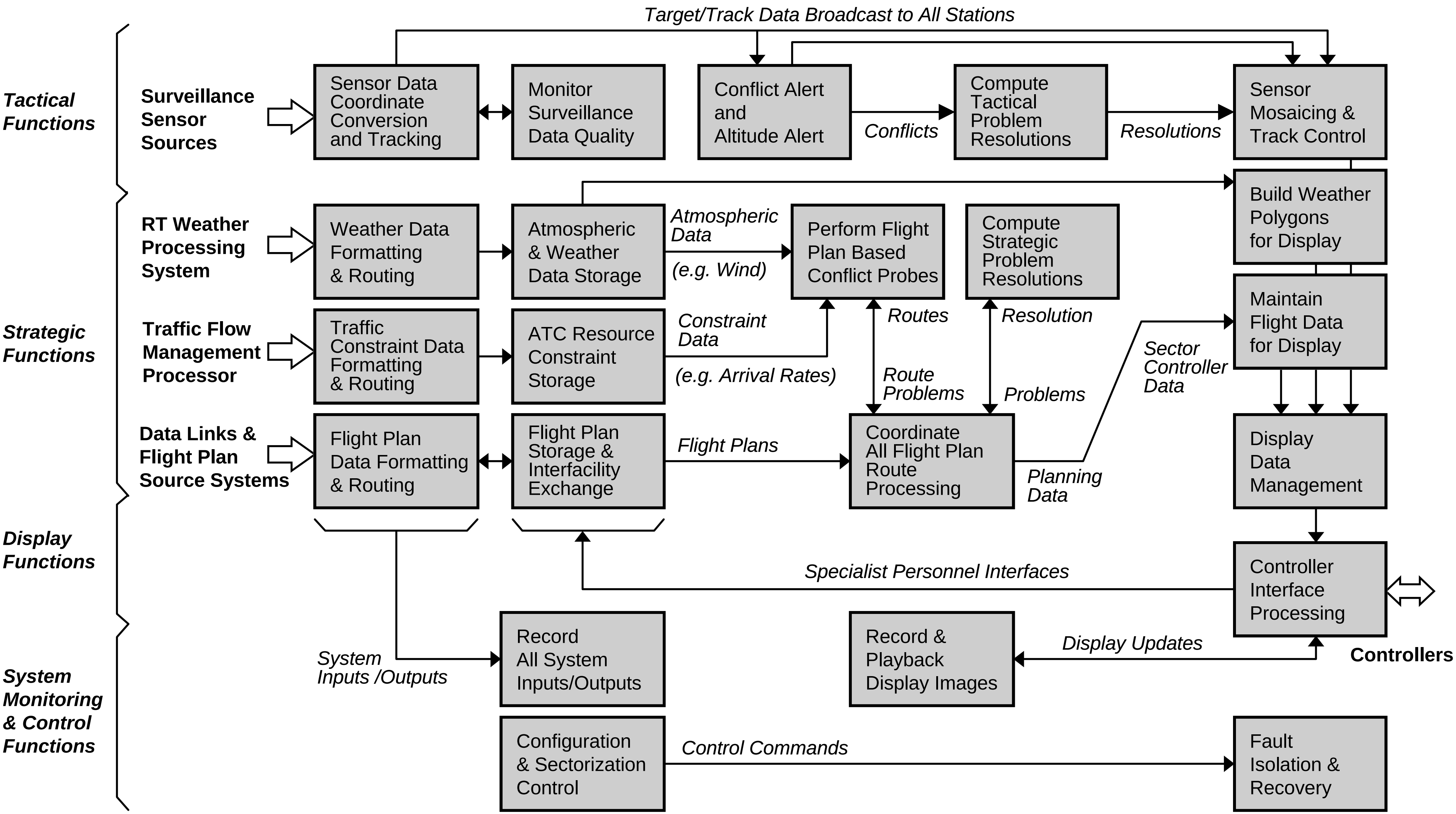


Equipment

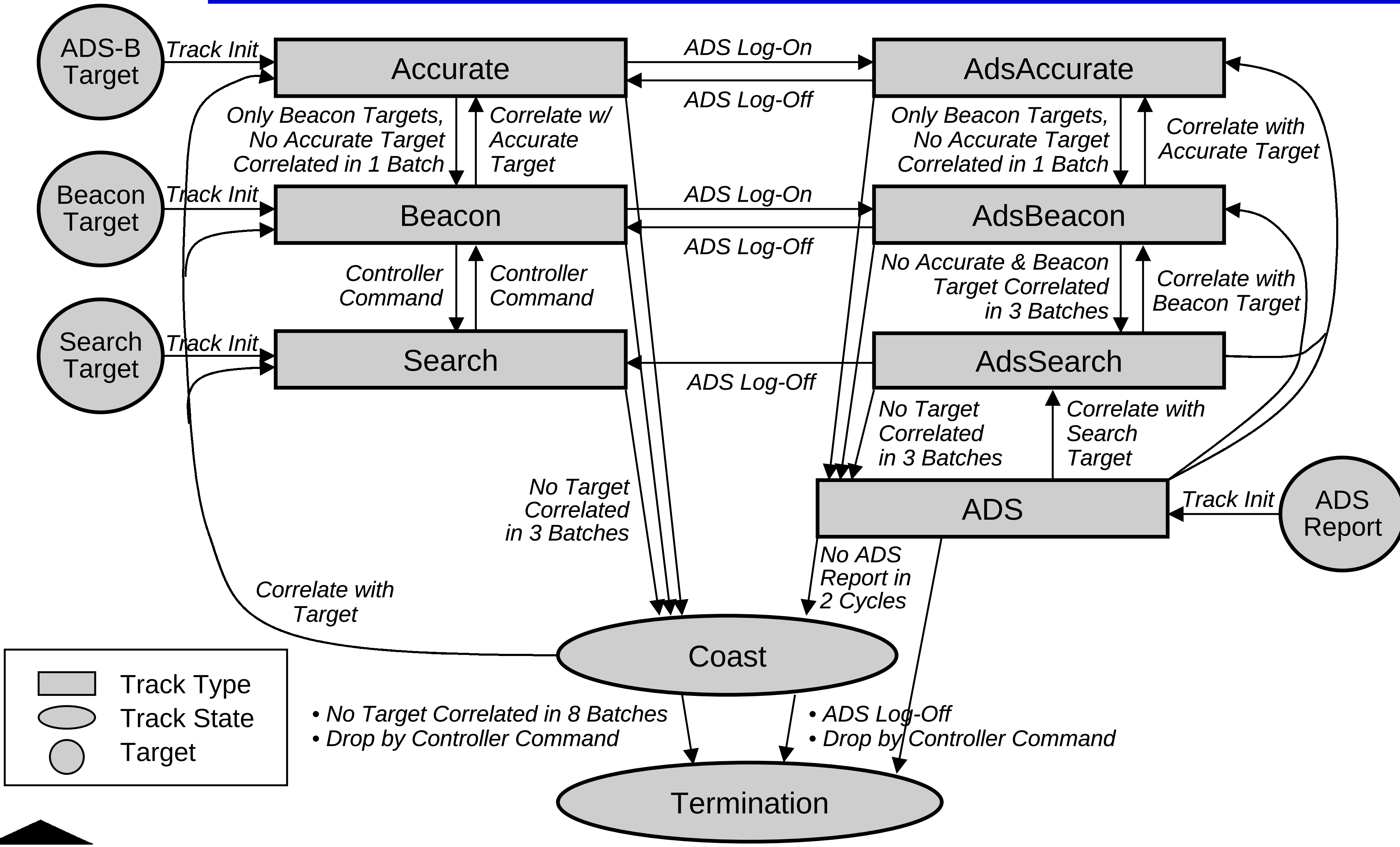
ATM System Architecture



ATM Function and Data Flow



Surveillance Data Fusion Processing



Safety Features in ATM

- **Conflict Alert & Conflict Probe:**
  - Conflict Alert (CA):
    Provides controller a 2~5 min advanced alert to potentially hazardous aircraft proximity situations using aircraft's track information (speed, heading & turn rate).
  - Conflict Probe (CP):
    A software tool for en-route controller to check a current flight plan or proposed flight plan for potential aircraft-to-aircraft conflicts in 20 min ahead of time.

- **Minimum Safe Altitude Warning (MSAW):**
  - General Terrain Monitoring (GTM):
    Monitors all non-approach path aircraft in the terminal area for potential terrain hazard based on aircraft speed/heading and digital terrain map (DTP) information and generates appropriate controller alert 30~480 sec in advance.
  - Approach Path Monitoring (APM):
    Monitors approach path aircraft based on its current reported altitude as compared with specified glideslope altitude (for ILS landing) or minimum descend altitude (for NPA) to generate a 15 sec advanced warning to controller.

- **Air Space Protection:**
  - Airspace Protection (AP):
    Detects intruders, spill-out and altitude violation aircraft in a specified airspace volume and generates alerts to controller.

Integrated FDP/CPDLC in ATM

CPDLC Uplink	CPDLC Downlink
• **Uplink CPDLC Messages (238)** – Responses/Acknowledgements (10) – Vertical Clearances (46) – Crossing Constraints (22) – Lateral Offsets (9) – Route Modifications (31) – Speed Changes (21) – Contact/Monitor/Surveillance Requests (11) – Report/Confirmation Requests (33) – Negotiation Requests (5) – Air Traffic Advisories (15) – System Management Messages (8) – Additional Messages (27) • **Uplink Message Attribute** – Urgent: Distress, Urgent, Normal, Low – Alert: High, Medium, Low, No – Response: W/U, A/N, R, Yes, No	• **Downlink CPDLC Messages (114)** – Responses (6) – Vertical Requests (10) – Lateral Offset Requests (3) – Speed Requests (2) – Voice Contact Requests (2) – Route Modification Requests (8) – Reports (35) – Negotiation Requests (8) – Emergency/Urgent Messages (9) – System Management Messages (7) – Additional Messages (18) – Negotiation Reponses (6) • **Downlink Message Attribute** – Urgent: Distress, Urgent, Normal, Low – Alert: High, Medium, Low, No – Response: Yes, No

• ICAO ATN SARPs (Standards and Recommended Practices) 3.0, 2001

Integrated FDP/AIDC in ATM

- **User-Confirmation Service**
  - User-confirmation service (for all other services)
- **Notifying Regime**
  - Notify service
- **Coordinating Regime**
  - Coordinate-start service
  - Coordinate-negotiate service
  - Coordinate-standby service
  - Coordinate-end service
- **Transferring Regime**
  - Transfer-initiate service
  - Transfer-conditions-proposal service
- **Transferring Regime (conti)**
  - Transfer-conditions-accept service
  - Transfer-request service
  - Transfer-control service
  - Transfer-communication service
  - Transfer-communication-assume service
- **Asynchronous Service**
  - Info-transfer service
- **Termination Services**
  - End service
  - User-abort service
  - Provider-abort service

- ICAO ATN SARPs (Standards and Recommended Practices) 3.0, 2001

Integrated FDP/PDC in ATM

- **Departure Clearance Format**
  - *Request for Departure Clearance (downlink)*
    - Message type identifier
    - Avionics display/printer capability
    - Flight information and gate identifier
    - ATIS identifier
    - Aircraft type notification
    - Additional information
  - *Departure Clearance (uplink)*
    - Message type identifier
    - Time and date
    - ATC identifier
    - Clearance indicator and number

- **Departure Clearance Format (conti)**
  - *Departure Clearance (conti)*
    - Cleared destination
    - Cleared runway departure and route
    - ATCRBS squawk
    - Departure time
    - Next frequency
    - Current ATIS
    - Optional free text
  - *Departure Clearance Readback (downlink)*
    - Message type identifier
    - Message contents (same as clearance uplink)

Air Traffic Flow Management in Taipei FIR

Aircraft Situation Display (ASD)

↓

Monitor & Alert (M&A)

↓

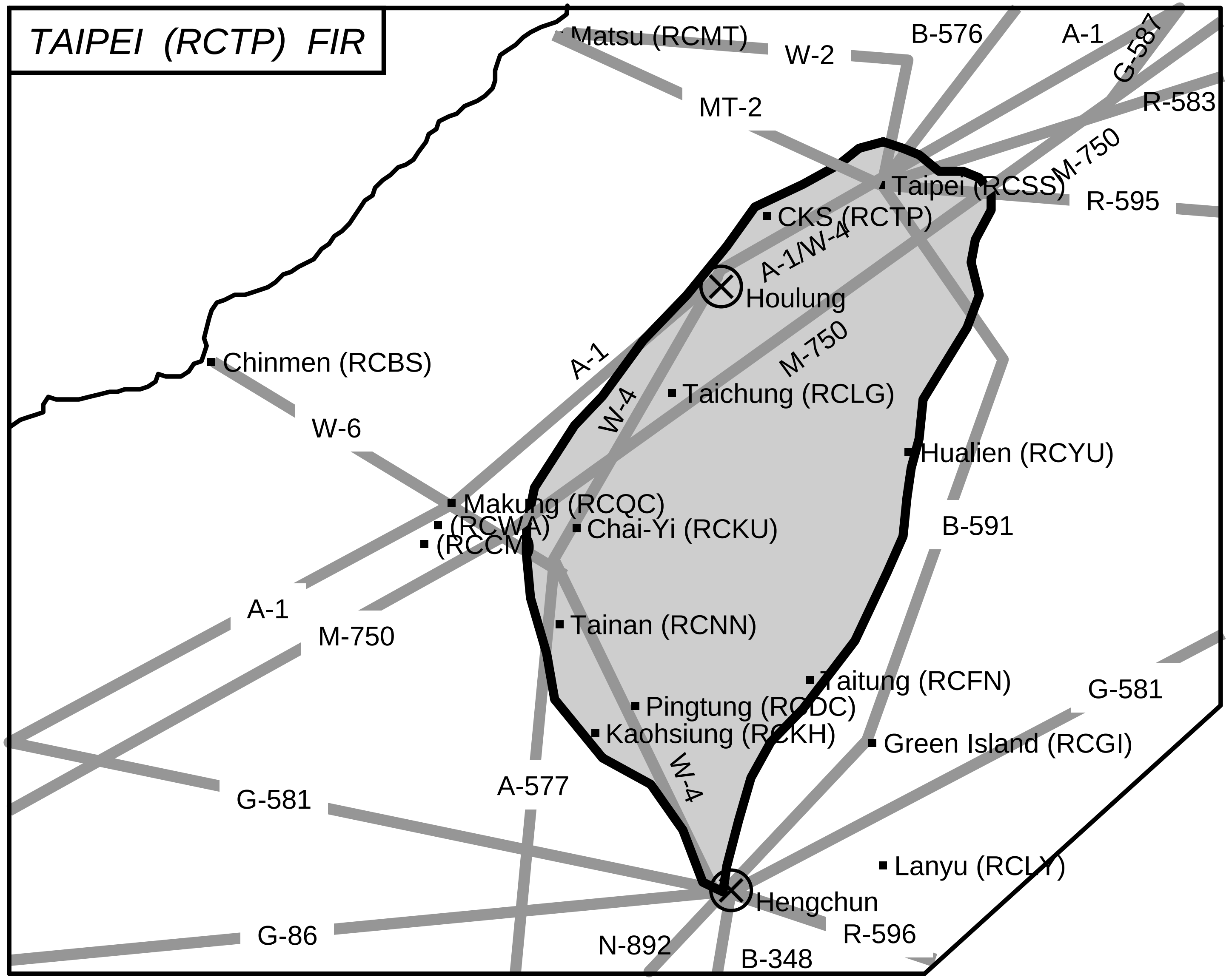
Automated Demand Resolution (ADR)

↓

Strategy Evaluation & Recommendation (SER)

↓

Directive Distribution Function (DDF)



Taipei FIR Airports & Landing Aids

Airport	ICAO	IATA	Landing Aids	Daily Flights (Jan 2002)
Taipei CKS International	RCTP	TPE	RWY 05/23: ILS CAT-II, RWY 06/24: ILS CAT-I	330
Kaohsiung International	RCKH	KHH	RWY 09L/27R: ILS CAT-I	246*
Taipei Sungshan	RCSS	TSA	RWY 10: ILS CAT-I, RWY 28: LDA	391*
Taichung	RCLG	TXG	RWY 36: MLS, NDB	91
Chiayi	RCKU	CYI	RWY 36: ILS CAT-I	43
Tainan	RCNN	TNN	RWY 36R: ILS CAT-I	61
Pingtung South	RCDC	PIF	RWY 09: ILS CAT-I	10
Hualien	RCYU	HUN	RWY 03: MLS, LDA	57
Taitung /Fengnin	RCFN	TTT	RWY 04: MLS, VOR	46
Makung	RCQC	MZG	RWY 02: ILS CAT-I	97
Chimei	RCCM	CMJ	VFR	6
Wang An	RCWA	WOT	VFR	0.6
Chinmen	RCBS	KNH	RWY 06: LDA/DME	51
Matsu	RCMT	MZW	NDB	11
Green Island	RCGI	GNI	VFR	11.4
Lanyu	RCLY	KYD	VFR	8.2

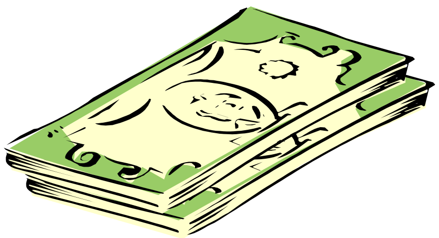
* ***Due to the heavy traffic between Taipei TSA and Kaohsiung KHH airports, the major ATFM problem in Taipei FIR is the capacities reduction in case of bad weather conditions in either airports***

Air Traffic Flow Management Functions

- **Aircraft Situation Display (ASD):**
  - Display real-time aircraft positions on a national scale superimposed on geographic map and airway routes.
  - Numerous filtering methods to select group of aircraft to be displayed.
- **Monitor-Alert (M/A):**
  - M/A compares demand and capacity of each focus of interest, including all airports, sectors, and fixes, and automatically generates alerts when projected demand exceeds capacity alert thresholds.
- **Automated Demand Resolution (ADR):**
  - Traffic imbalance resolving strategies will be developed using a knowledge-based traffic management tool in ADR.
- **Strategy Evaluation and Recommendation (SER):**
  - SER examines all alternate strategies generated by ADR and ranks them based on rules and preferences determined by ATM specialists.
- **Directive Distribution Function (DDF):**
  - After the best strategy being selected, DDF formulates required data messages, and sends them to appropriated entities.

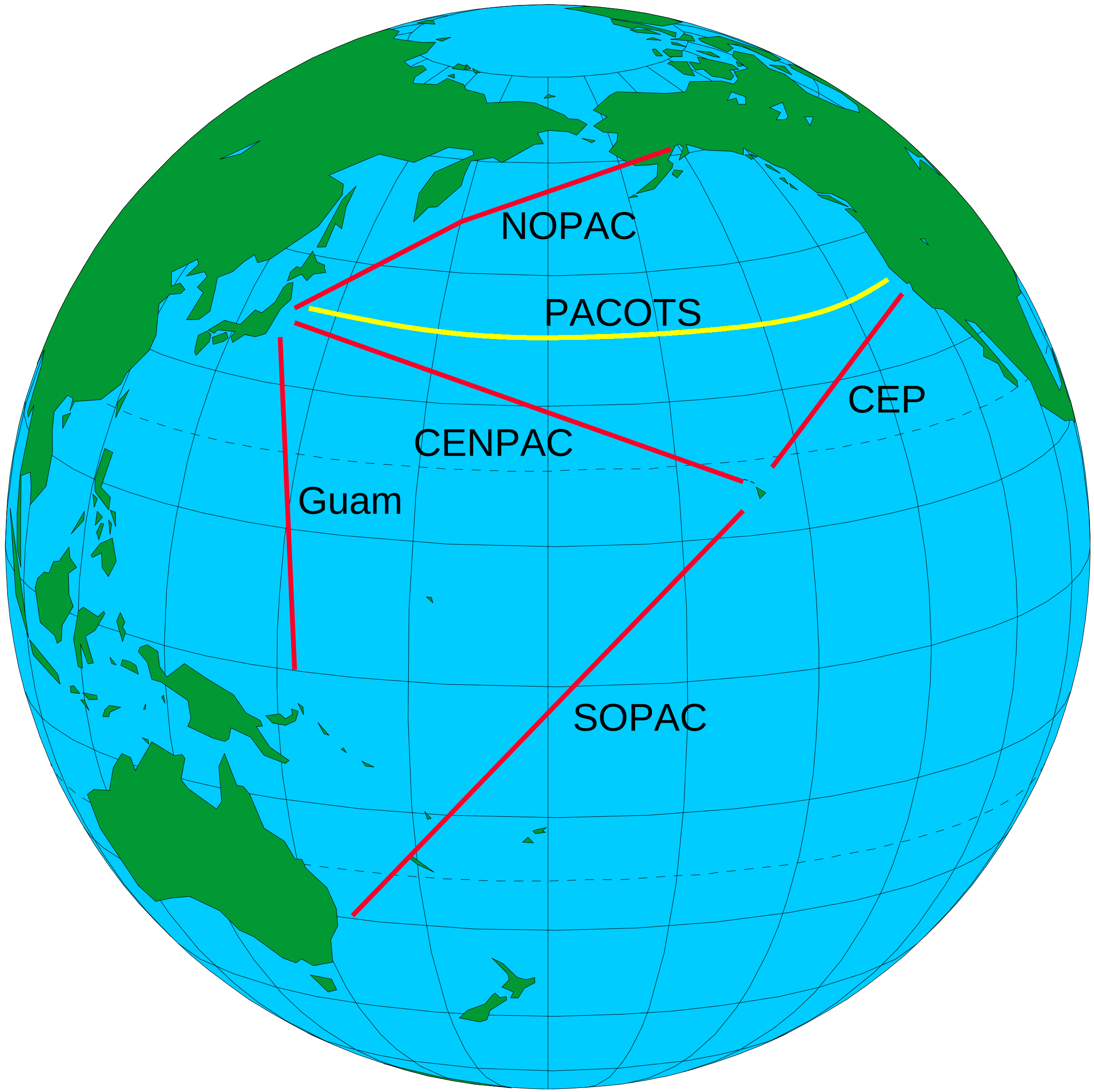
Global & Regional Air Transportation

Airline Selection of Flight Routes



- Volume of Passengers and Freights
- Time and Fuel Savings
- Required Aircraft Equipment and Available ATS & Emergency Services

Pacific Oceanic Routes



Pacific Oceanic Route Systems

- **Pacific Organized Track System (PACOTS):**
  - Flexible track system between Asia/Australia/New Zealand and North America/Hawaii.
  - Oakland and Tokyo ATC centers develop and publish flexible tracks for these routes twice daily to take advantage of changing wind forecasts.

- **Pacific Oceanic Composite Route Systems (CRS):**
  - North Pacific (NOPAC):
    - Routes between Japan and Alaska including 5 fixed tracks and 9 transition routes.
  - Central Pacific (CENPAC):
    - Including PACOTS routes between Japan and Hawaii, Japan and the US west coast, and fixed tracks connecting US/Canadian Pacific northwest to Hawaii.
  - Central East Pacific (CEP):
    - Including 7 fixed routes connecting US central west coast to Hawaii.
  - South Pacific (SOPAC):
    - Including PACTOS tracks between San Francisco/Los Angeles and Sydney/ Auckland, and fixed tracks between Hawaii and South Pacific.
  - Guam-Area Routes:
    - Contains fixed routes connecting Northeast Asia to South Pacific.

Pacific Organized Track System (PACOTS)

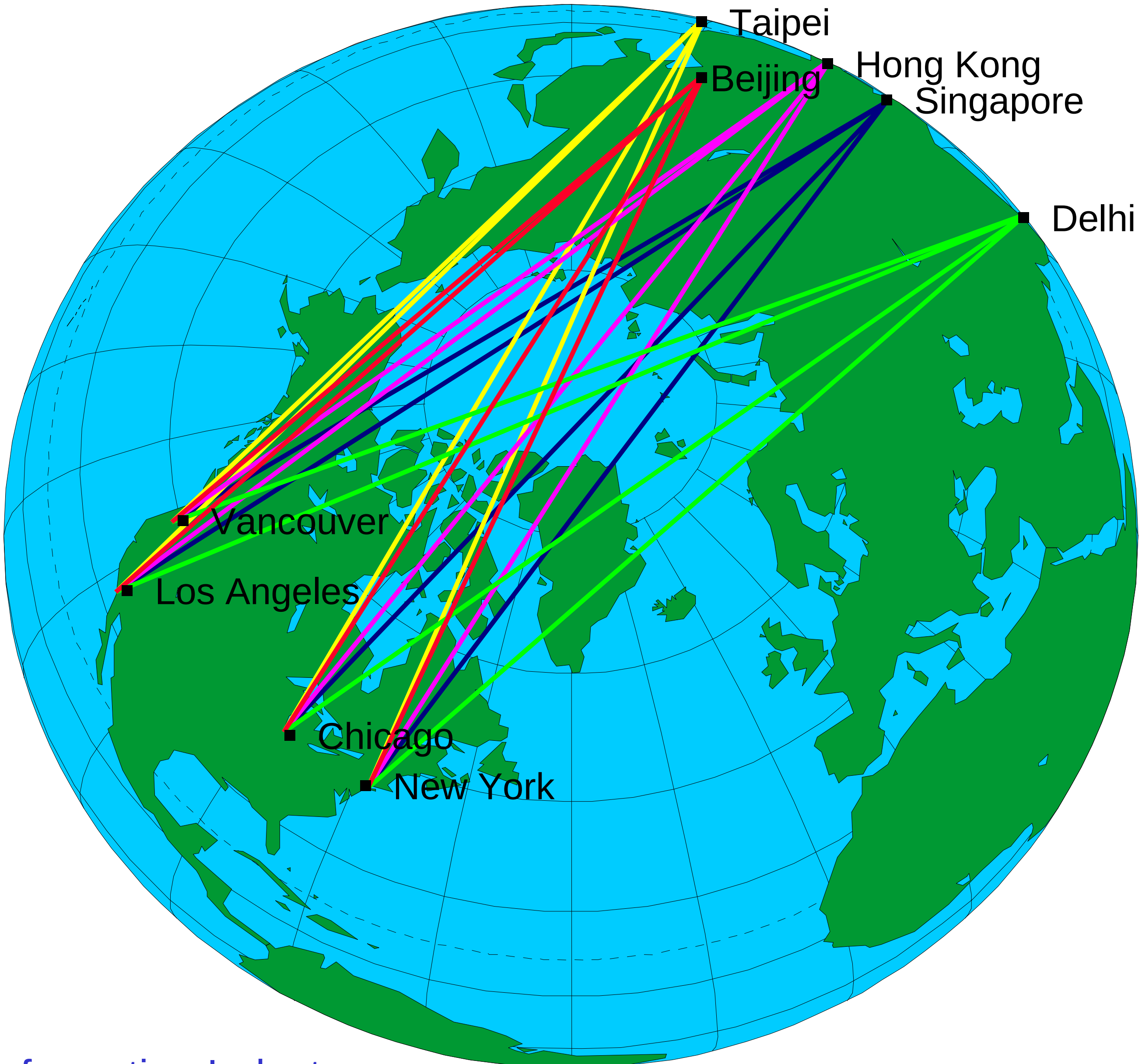
PACOTS Track	Origin / Destination	Separation Minima
Track 1	Japan to Pacific Northwest	• The nominal lateral separation minimum for north of 30N is 50 nm for RNP-10 approved aircraft in the entire route of flight. The nominal track spacing for south of 30N latitude is 100 nm. • The standard longitudinal separation minimum is 15 minutes, although Mach number techniques can be used to reduce in-trail times to a nominal 10 minutes. • The vertical separation minimum is 1000 feet between FL 290 and 410 for RVSM approved aircraft. Aircraft not approved for RVSM may operate above FL 390 using 2000 feet vertical separation.
Track 2	Japan to San Francisco	
Track 3	Japan to Los Angeles	
Track 4	Japan to West Coast US	
Track 8	Japan to Dallas	
Track 11 & 12	Japan to Honolulu	
Track 14 & 15	***Taipei/Hong Kong to San Francisco/Los Angeles***	
Track 20	Sydney to Los Angeles	
Track 21	Auckland to Los Angeles	
Track A & B	Honolulu to Japan	
Track C - G	West Coast US to Japan	
Track H - K	***West Coast US to Taipei/Hong Kong***	
Track L	West Coast US to Manila	
Track M	Dallas to Japan	
Track W	Los Angeles to Sydney	
Track X	Los Angeles to Auckland	

• *Note: Oakland and Tokyo ATC centers develop and publish flexible tracks for PACOTS routes twice daily to take advantage of changing wind forecasts*

Pacific Oceanic Airspace Initiatives

- **Reduced Vertical Separation Minimum (RVSM):**
  - Reduce the vertical separation between FL 290 and FL 410 from 2000 feet minimum to 1000 feet minimum, and to provide fuel savings and operational efficiencies for airspace users.
- **Reduced Horizontal Separation Minimum (RHSM):**
  - Reduce the horizontal separation minimum from 100 nm lateral, 100 nm longitudinal to 50/50 nm or 30/30 nm for oceanic air routes.
- **In-Trail Climb/In-Trail Descent (ITC/ITD):**
  - Use of the Airborne Collision Avoidance System/Traffic Alert and Collision Avoidance System (ACAS/TCAS), air-to-air VHF and HF communications, and Automatic Dependent Surveillance-Broadcast (ADS-B) in the future to do in-trail following.
- **Dynamic Aircraft Route Planning (DARP):**
  - Allow operator to update/revise the flight route to a more efficient trajectory for an en-route aircraft once a revised weather forecast is available and a new track is published.
- **User Preferred Route (UPR):**
  - UPR are the most economical routes based on the airlines' own data as opposed to ATC published routes.

Polar Routes



Benefits & Restrictions of Polar Routes

- **Polar Routes Benefits:**
  (Saves Time and Fuel)
  - Offer distance savings up to 1,000 nm, or more than 2 hours of flight time over other tracks between North American and Far East cities
  - Can eliminate stopovers

- **Polar Routes Operational Restrictions:**
  (Lack of Infrastructure)
  - No ATC radar
  - No ground-based navaids
  - SatCom signals are unreliable above 75^{o}
  - Search and rescue forces could take days to reach an accident scene
  - Emergency airfields are ill-equipped to house stranded crews and passengers

Polar Route Fly Savings (1)

City Pair	Current Distance (nm)	Polar Route Distance (nm)	Saving Per Flight (nm)	Saving Per Flight (Minutes)*
Atlanta - Seoul	7,138	6,190	948	124
Boston - Hong Kong	7,966	6,909	1,057	138
Boston - Seoul	6,818	5,911	907	118
Chicago - Delhi	7,483	6,487	996	130
Chicago - Hong Kong	7,787	6,753	1,034	135
Chicago - Manila	8,129	7,053	1,076	140
Chicago - Seoul	6,538	5,668	870	113
Denver - Seoul	6,187	5,361	826	108
Detroit - Beijing	6,633	5,746	887	116
Detroit - Seoul	6,623	5,742	881	115
Detroit - Taipei	7,542	6,540	1,002	131
Houston - Seoul	6,825	6,112	713	93
Los Angeles - Bangkok	8,259	7,167	1,092	142
Los Angeles - Beijing	6,252	5,417	835	109
Los Angeles - Delhi	8,011	6,948	1,063	139
Washing DC - Seoul	6,949	6,023	926	121

** Based on 460 knots ground speed*

Source: Business & Commercial Aviation, December 2001

Polar Route Fly Savings (2)

City Pair	Current Distance (nm)	Polar Route Distance (nm)	Saving Per Flight (nm)	Saving Per Flight (minutes)*
Minneapolis - Hong Kong	7,494	6,498	996	130
Minneapolis - Singapore	9,055	7,879	1,176	153
New York - Beijing	6,833	5,926	907	118
New York - Delhi	6,633	5,747	886	116
New York - Dhaka	7,882	6,833	1,049	137
New York - Hong Kong	8,060	6,997	1,063	139
New York - Seoul	6,885	5,987	907	118
New York - Shanghai	7,386	6,410	976	118
New York - Singapore	9,884	8,287	1,606	209
New York - Taipei	7,798	6,770	1,028	134
San Francisco - Bangkok	7,925	6,875	1,050	137
San Francisco - Beijing	5,915	5,124	791	103
Seattle - Seoul	5,199	4,413	786	103
Vancouver - Beijing	5,409	4,584	825	108
Vancouver - Hong Kong	6,489	5,533	956	125
Vancouver - Taipei	6,074	5,176	898	117

** Based on 460 knots ground speed*

Source: Business & Commercial Aviation, December 2001

Status of Polar Routes

- Currently 3 airlines make regular flights over Arctic with 2~3 trans polar flights each day:
  - United:
    - Chicago to Hong Kong daily
    - Chicago to Beijing daily
  - Northwest:
    - Detroit to Beijing 4 flights a week
  - Continental:
    - Newark to Hong Kong 4 flights a week
- Russian authorities estimate:
  - Polar routes will reach 40 flights each day by 2010.
  - Income of overflight fee from polar routes will reach $180 million between 2001 and 2010.
  - A 10-year upgrade and consolidation program is planned to modernize the ATS infrastructure throughout Russia.

City Pair	Time Savings Per Flight	Money Savings Per Flight
Atlanta - Seoul	124 minutes	$44,000
Boston - Hong Kong	138 minutes	$33,000
Los Angeles - Bangkok	142 minutes	$33,000
New York - Singapore	209 minutes	$44,000
Vancouver - Beijing	108 minutes	$33,000
Vancouver - Hong Kong	125 minutes	$33,000

- *Source: Avionics Magazine, April 2002*
- *Study done by Nav Canada and the Federal Aviation Authority of Russia*

Global & Regional Air Transportation

- Pacific FANS Routes:
  - Airlines are using PACOTS FANS routes today.
  - No existing FANS routes from East Asia to west coast of America are starting from, directly connect to or flying over Taipei FIR. Airlines are going through Tokyo FIR to connect to PACOTS routes.

- Polar Routes:
  - Polar routes will cut time and fuel for airline revenue flights between North American and Far Eastern cities.
  - Currently no polar flights between Taipei FIR and other cities in the world.
  - Flying the polar routes from Taipei FIR to North American cities requires overflight through mainland China and Russia's airspace.

Conclusion - CNS/ATM

Cool New Stuff, All Takes Money