Air Traffic Infrastructure
Global Markets 2012
World Forecasts 2012 - 2021

MARKETS • POLICIES • INFRASTRUCTURE FINANCE

FEATURING

- ☒ The Inflection Point Facing World ATI Markets
- ☒ The New Economics of ATI, Including Infrastructure Finance
- ☒ Disruptive and Rapidly Emerging Technologies Challenging NextGen and SESAR

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Dear Subscriber:

The world's air traffic infrastructure (ATI) and its complex modernization programs are at a technical, policy and financial crossroad. As air traffic volumes recover from the latest global recession, congestion and gridlock are again becoming visible. But aviation infrastructure continues to erode. Governments are broke and must turn to new fees, taxes, and private sources of funding for infrastructure renewal. Disruptive new technologies and regional differences in the vision of future ATI architectures will challenge the Next Generation Air Transportation System (NextGen) and Single European Sky ATM Research (SESAR) programs. Airlines, coming out of a difficult decade of losses, find that they may foot most of the bill for ATI modernization, whether through investment in avionics or through increased user fees to pay for new ground infrastructure. Airlines are quickly realizing that they are and should be the new gate keepers for ATI modernization. All the while, aerospace companies are trying to understand the new ATI market dynamics, as corporate acquisitions work their way back into merger and acquisition agendas for 2013.

The genesis of ATI Global Markets 2012 is what we perceive as a need on the part of our aerospace clients active in the global air traffic management marketplace, for an integrated, comprehensive view of changing system policies, technologies, finances and market potential. Air Traffic Infrastructure Global Markets 2012 will be an essential tool for business strategists and top executives alike, providing facts and insights to support business planning and investment decision-making. Packed with information on air traffic infrastructure opportunities, communications, navigation, surveillance/air traffic management, NextGen, SESAR, and their rapidly evolving successor systems, aircraft avionics, and space systems, ATI Global Markets 2012 does the heavy lifting. It provides comprehensive opportunity assessments of ATI markets in 60 countries selected from all ICAO regions. Of tremendous value, ATI Global Markets 2012 lays out the new economics of ATI finance. This study is a must-have for top executives, providing the factual foundation for answering key questions to support strategic decision-making.

We expect and welcome feedback from our subscribers as to ways in which the document can be modified or enhanced to provide ever greater value.

Sincerely,

Michael J. Dyment, Managing Editor

Russell G. Chew, Editorial Advisor

Acknowledgments

Much of the research information contained herein came from sources we wish to acknowledge gratefully, including ICAO (Montreal, QC), the FAA (Washington, DC), the Library of Congress (Washington, DC), and the libraries of the Massachusetts Institute of Technology (Cambridge, MA), Transport Canada (Ottawa, ON) and the World Bank (Washington, DC). As the CNS/ATM plans of over 60 countries were considered, we thank those within CANSO, and the many, many ANSPs and embassies who provided us with information regarding all facets of their countries' air traffic modernization programs and needs.

We wish to give our enthusiastic thanks to the conscientious researchers and analysts who contributed extensively to the contents of this study, Marquitta Winston, Christina Nutting and Sharon Mall. Proofing assistance and a sharp pen came from several permanent and consulting members of the NEXA Advisors team, and we single out for special thanks Eleanor Herman Dyment, our resident *New York Times* bestselling author, for her meticulous attention to both fact and publishing detail.

This project consumed more time than we had initially anticipated, and we therefore want to thank our Charter Subscribers for their patience and endurance, without which this report would not have been possible.

MJD

Air Traffic Infrastructure Global Markets 2012

Editorial Board

The authors and contributing editors of the 2012 edition of *Air Traffic Infrastructure Global Markets 2012* are introduced, with a brief biography, below.

Michael J. Dyment, Managing Editor

Mr. Dyment is the founder and managing partner of NEXA Capital Partners and NEXA Advisors. He is also a founder and general partner of The NextGen Equipage Fund.

Prior to NEXA, Mr. Dyment was a partner, senior managing director or principal with the aerospace practices of PricewaterhouseCoopers LLP, Arthur Andersen LLP, and Booz Allen & Hamilton Inc. He was also an officer and vice president of the Transportation Practice of A.T. Kearney, Inc. When at PwC, he was principal advisor to ITT on its 2007 $1.85 billion ADS-B award from the US FAA. Mr. Dyment's past clients include the world's leading aerospace companies, such as the Boeing Company, Embraer Empresa Brasileira de Aeronáutica S.A., Lockheed Martin Corporation, Inmarsat, and Rolls-Royce, to name a few. Airline and aviation industry clients include brand names such as Delta Airlines, Lufthansa, Swiss, EasyJet, Grupo TACA, and Orbitz. He has been an advisor to top policy makers and agencies such as the FAA, the US Transportation Security Administration, and the National Academy of Sciences. At A.T. Kearney, he led the acquisition and financial advisory team that ultimately secured the $1 billion purchase of Jet Aviation for Permira Beteiligungsberatung GmbH. His career in aerospace began in the supply chain, where in the early 1980s he was an engineer and product manager for GPS avionics and geodetic programs at Canadian Marconi Company in Montreal. While at Booz Allen, Mr. Dyment was author of the ground-breaking 1996 multi-client study, *Air Traffic Control and Air Traffic Management Systems: An Analysis of Policies, Technologies, and Global Markets.* This study established a global industry understanding of CNS/ATM for the 21st century for many companies. Upon completion of the study, he advised many aerospace companies on CNS/ATM strategy and authored numerous articles relating to air traffic management, with a keen focus on both technology and market issues.

A popular and respected speaker on aerospace matters, his opinion is regularly sought by the media. He has been quoted in *The Wall Street Journal, The International Herald Tribune, The Financial Times* and *The Los Angeles Times.* He has contributed to stories in *Forbes Magazine, Wired Magazine,* and *Business Week* and has been a guest on CNN, MSNBC, CBS, and ABC, offering insights on aerospace industry matters. Currently, he is a member of the *Aviation Week Magazine* Board of Advisors on Top Performing Aerospace Companies and Top Performing Airlines.

Mr. Dyment holds a Master of Science in Aeronautics and Astronautics from the Massachusetts Institute of Technology, and a B.Sc.E. in Geodesy and Geomatics from the University of New Brunswick.

Russell G. Chew, Editorial Advisor

Mr. Chew is a managing partner of NEXA Capital Partners and NEXA Advisors. He is a general partner of The NextGen Equipage Fund. Some call Mr. Chew the "Father of NextGen." While serving as chief operating officer of the Air Traffic Organization of the FAA, he set the groundwork for the current program architecture and structures. As COO, Mr. Chew was responsible for the operational and financial performance of the US air traffic control system and research and acquisition programs from 2003 to 2007.

After his years at the FAA, Mr. Chew served as president and COO of JetBlue Airways during the successful turnaround in its business model, sustained profitability, and operational integrity following its highly publicized operating debacle in the February 2007 snowstorm.

Prior to joining the FAA, Mr. Chew spent 18 years with American Airlines, Inc. where he headed System Operations Control and was responsible for performance of the airline's operation of 2,300 flights daily to more than 220 cities in the US, Europe, Latin America, and Asia. He was responsible for the airline's evaluation, acquisition, and implementation of new aircraft and ground technologies for airline fleet and operations planning. He performed technical and regulatory management in flight operations, systems development, and engineering and maintained line qualification as captain at American Airlines in B767, B757, and MD80 air-craft.

He has served on corporate executive boards and activities focused on airline operations, new technologies/air traffic control system requirements, and global air traffic control modernization programs. Mr. Chew attended Stanford University for his undergraduate studies and earned his doctoral degree at the University of Southern California.

James P. Hughey, Contributing Editor

Mr. Hughey is Senior Vice President at NEXA Capital Partners and an experienced financial professional with operational and strategic expertise in the logistics, transportation, and technology sectors where his roles have ranged from operations management to consulting and private equity/venture capital. He supports both NEXA and its clients in shaping business strategy and growing enterprise value through corporate finance advisory and structured investment transactions.

In a management consulting role with Accenture, he advised several government agencies as well as private clients on logistics and technology issues ranging from strategic resource allocation to asset management and workforce efficiency. As an industrial engineer with UPS, he managed package operations planning and supervised the technical implementation of industry-leading programs within the sorting and delivery functions.

Mr. Hughey earned his MBA from The Darden School of Business and dual Bachelor of Science degrees in Industrial Engineering and Manufacturing Engineering from Northwestern University.

Carter Brockman, Contributing Editor

Mr. Brockman is a senior analyst with NEXA Advisors. He assists NEXA and its clients with key investment analysis and due diligence efforts throughout the financing lifecycle. He is a key contributor on global aviation and air traffic infrastructure projects, including modernization programs and next generation technologies.

Mr. Brockman holds a Master of Business Administration and a Bachelor of Science in Aerospace Engineering with a specialization in propulsion from Embry-Riddle Aeronautical University in Daytona Beach, FL. Mr. Brockman also holds a private pilot certificate.

Tulinda Larsen, Market Analyst

Tulinda Larsen contributed to NEXA's econometric forecast models of ATI industry and market demand. She brings more than 30 years of transportation industry expertise to develop strategic and technical solutions for clients. Prior to joining NEXA, Ms. Larsen directed analytical, consulting, and research services for several transportation companies, including SH&E and OAG. She provided extensive market research and forecasting services to aircraft engine and aircraft manufacturers including G.E., Pratt & Whitney, Japanese Aero Engines Corporation, Bombardier Regional Aircraft Division, Saab Aircraft, Embraer, Fairchild Dornier/AvCraft, Raytheon (Beech Aircraft), China's AVIC, and the new turboprop freighter, Skylander. She has advised regional aircraft financial companies, including IHI, Export Development Bank of Canada, AeroCentury Aircraft Leasing, and G.E. Commercial Aviation Services.

She is a private pilot, past-president (2001) of the Aero Club of Washington DC, member of the board of directors (2005-2006) of International Trade Data Users, member of the board of directors of the International Aviation Club, member of the International Aviation Woman's Association, the Royal Aeronautics Society, and various committees of the Transportation Research Board, National Academies.

Ms. Larsen holds a Master's degree in Economics and a Bachelor's in Political Science from The George Washington University. She is candidate for a doctorate in management (2013).

NEXA Project Team

A dedicated, cross-functional team of NEXA professionals was assembled for this project. Each team member has a unique understanding and discipline to apply, including research, policy expertise, CNS/ATM technology understanding, market forecasting, financial and cost benefit modeling, investment banking, and infrastructure finance.

NEXA Advisors Overview

ATI Global Markets 2012 is a NEXA Advisors project. NEXA Advisors provides strategic advisory services to the aerospace industry. Clients seek out NEXA Advisors to help develop transformational business models in the aerospace supply chain, business aviation, air traffic management, homeland security, energy, and clean technologies and geomatics.

NEXA Advisors is a member of NEXA Capital Partners, an investment banking firm helping clients develop and implement effective corporate finance, capital investment, and M&A strategies leading to higher growth in enterprise value. NEXA has served small, mid-market, and large aerospace companies since 2007. In 2010, NEXA Capital Partners founded The NextGen Equipage Fund, LLC, a new investment fund created to accelerate equipage of US registered aircraft with NextGen avionics. The NextGen Fund is an innovative $1.5 billion infrastructure fund, whose investors include some of the largest aerospace companies in the world.

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ACRONYMS

A	Radio Altitude
AC, A/C or ACFT	Aircraft
ACC	Area Control Center
ACARS	Aircraft Communication and Addressing Reporting System
ACAS	Airborne Collision Avoidance System
ACI	Airports Council International
ACMS	Aircraft Condition Monitoring System
AD	Airworthiness Directive
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance-Broadcast
ADS-C	Automatic Dependent Surveillance-Contract
AEA	Association of European Airlines
AFS	Aeronautical Fixed Service
AFTN	Aeronautical Fixed Telecommunication Network
AIP	Aeronautical Information Publication
ALS	Approach Lighting System
ANSP	Air Navigation Service Provider
AOA	Angle of Attack
AOC	Air Operator's Certificate
AOC	Airline Operations Center
AOM	Airport/Aerodrome Operating Minima
APU	Auxiliary Power Unit
ARPT	Airport
ARSR	Air Route Surveillance Radar
ARTCC	Air Route Traffic Control Centers
ASAS	Airborne Separation Assurance System
ASM	Airspace management
ASPIRE	Asia and South Pacific Initiative to Reduce Emissions
ASR	Airport Surveillance Radar
A4A	Airlines for America
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATCSCC	Air Traffic Control System Command Center
ATCT	Airport Traffic Control Tower
ATFM	Air Traffic Flow Management
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
ATS	Air Traffic Services
CAA	Civil Aviation Authority
CARATS	Collaborative Actions for Renovation of Air Traffic Systems (Japan)
CDM	Collaborative Decision Making
CDU	Control/Display Unit
CFIT	Controlled Flight Into Terrain
CNS	Communications, Navigation, and Surveillance
COMPASS	Global Navigation Satellite System (China)
ConOps	Concept of Operations
COTS	Commercial Off-The-Shelf
CPDLC	Controller Pilot Data Link Communications
CVR	Cockpit Voice Recorder
DME	Distance Measuring Equipment
DoD	Department of Defense
EAS	Equivalent airspeed
EASA	European Aviation Safety Agency
EFIS	Electronic Flight Instrument System
EGNOS	European Geostationary Navigation Overlay Service
EGPWS	Enhanced Ground Proximity Warning System
EIB	European Investment Bank
EICAS	Engine Indicator and Crew Alert System
E-LSA	Experimental light-sport aircraft
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration
FANS	Future Air Navigation System
FBO	Fixed Base Operator
FDR	Flight Data Recorder (also known as black box)
FIC	Flight Information Region
FIR	Flight Information Region
FL	Flight Level
FMC	Flight Management Computer (same as FMS)
FMS	Flight Management System
FPL	Filed Flight Plan
FSS	Flight Service Station

GA General Aviation
GALILEO Global Navigation Satellite System (Europe)
GBAS Ground Based Augmentation System
GCA Ground-controlled approach
GEO Geostationary Earth Orbit
GLONASS Global Navigation Satellite System (Russia)
GLS GNSS Landing System
GND Ground
GNSS Global Navigation Satellite Systems
GP Glide Path
GPS Global Positioning System
GPWS Ground Proximity Warning System
GSE Ground Support Equipment
HF High Frequency
HUD Head-up display
Hz Hertz
IAP Instrument approach procedure
IAS Indicated airspeed
IATA International Air Transport Association
ICAO International Civil Aviation Organiza tion
IFR Instrument Flight Rules
ILS Instrument Landing System
IMC Instrument Meteorological Conditions
INS Inertial Navigation System
IRS Inertial Reference System
ISA International Standard Atmosphere
ISFD Integrated Standby Flight Display
ISIS Integrated Standby Instrument System
KA Radio Frequency Ka
kHz Kilohertz
Kts Knots
Ku Radio Frequency Ku
L1 GPS Standard Positioning Service L-band ranging signal
L1 Carrier "Link" Frequency 1575.42Mhz
L2 GPS Precision Positioning Service L-band ranging signal
L2 Carrier "Link" Frequency 1227.6 Mhz
L3 Carrier "Link" Frequency 1385.05 Mhz
LAADR Low Altitude Arrival/Departure Routing
L-BAND Frequency from 390Mhz to approximately 1.55Ghz
LCC Low Cost Carrier
LEO Low Earth Orbiting
LLWAS Low-Level Wind shear Alert System
LNAV Lateral Navigation
LORAN Long Range Navigation System
LRU Line-replaceable unit
MATS Manual of Air Traffic Services
MDA/H Minimum Descent Altitude/Height
MEO Medium Earth Orbit
METAR Meteorological Aerodrome Report
MLAT Multilateration
MLS Microwave Landing System
MODE S Mode Select
MRO Maintenance Repair Overhaul
MSA Minimum Safe Altitude / Minimum Sector Altitude
MSL Mean Sea Level
MSSR Monopulse Secondary Surveillance Radar
MTOW Maximum Take-Off Weight
MZFW Maximum Zero-Fuel Weight
NAS National Airspace System
NASA National Aeronautics and Space Administration
NAVAID Navigational Aid
NDB Non-Directional Beacon
NextGen Next Generation Air Transportation System
NM Nautical Mile
OBS Omni-Bearing Selector
OEM Original Equipment Manufacturer
OTS Out of service
PAR Precision Approach Radar
PBD Place Bearing Distance (RNAV waypoint)
PENS Pan-European Network Service
PFD Primary Flight Display
PPP Public-Private Partnership
RNAV Area navigation
RNP Required Navigation Performance
RRTES Reroutes
RSLS Runway Status Light System
RSR En-route Surveillance Radar
RTCA Radio Technical Commission for Aeronautics
RVSM Reduced Vertical Separation Minimum
S/W Microwave Frequency between 2 and 4 Ghz
SATCOM Satellite Communications

SATNAV	Satellite Navigation
SBAS	Satellite-Based Augmentation System (SBAS)
SES	Single European Sky
SESAR	Single European Sky ATM Research
SID	Standard Instrument Departure
SOC	Start of Climb at Missed Approach
SOE	State-Owned Enterprise
SSR	Secondary Surveillance Radar
STC	Supplemental Type Certificate
SV	Space Vehicle
SWIM	System Wide Information Management
TAA	Terminal Arrival Area
TACAN	Tactical Air Navigation
TAM	Total Airport Management
TAR	Terminal Approach Radar
TAS	True airspeed
TCA	Terminal control area
TCAS	Traffic Collision Avoidance System
TDLS	Tower Data-Link Service
TDM	Time Division Multiplex
TDMA	Time Division Multiple Access
TO/GA	Take-off/go around
TOD	Top of Descent
TOW	Take-off weight
TOWS	Take-off warning system
TRACON	Terminal Radar Approach Control
UAC	Upper Area Control
UAV	Unmanned Air Vehicle
UHF	Ultra High Frequency
UTC	Universal Coordinated Time
VDL	VHF Datalink
VFR	Visual flight rules
VHF	Very High Frequency
VMC	Visual meteorological conditions
VNAV	Vertical Navigation
VOR	VHF omnidirectional range
WAAS	Wide Area Augmentation System
WTO	World Trade Organization
XPDR / XPNDR	Transponder
Z	Zulu Time (UTC)

Introduction

This study takes a unique approach to analyzing the global ATI market. Most analyses have focused on the air traffic that departs from or arrives in a country or its airports. That data tells only part of the story. ATI also serves aircraft that transit a nation's airspace without departing from or landing there. This overflight traffic can be significant for air navigation service providers (ANSPs) that lie along major international air routes, accounting in some cases for 60 percent or more of annual revenues. Traffic on long-range airline flights traditionally has grown faster than shorter-range segments and is expected to continue outpacing those segments' growth.

As the communications, navigation, and surveillance (CNS) and air traffic management (ATM) systems and capabilities that make up ATI erode, air transportation is growing in both numbers and complexity. Forecasters see air traffic resuming its traditional global growth rate through 2021, with much of the projected growth coming outside the big markets of North America and Europe. Traffic is shifting south and east into Asia, the Middle East, Latin America, and Africa. This reflects ongoing globalization of trade that is increasing business activity in those regions. Throughout the world, greater portions of populations are being drawn to urban areas. The number of cities with at least five million residents will swell throughout our forecast period. Many of those residents will realize greater income, increasing their propensity to travel. New routes and destinations and growth for established ones will dictate more efficient designs of airspace and air traffic procedures, as well as predictive and flexible systems to implement those changes.

Today's ATI is not scalable to handle such growing activity and complexity. This has been demonstrated by recent instances of gridlock that had global impact, as well as by longstanding warnings that problems will worsen without widespread, coordinated ATI modernization at and above the national level. The ability of today's fragmented air navigation systems to avert or mitigate such disruptions (and their resultant economic harm) with ad hoc solutions is nearly exhausted.

Systematic, long-term solutions are at hand, forged through aviation's relentless and continuing technological advance. As traffic growth increases the need for their prompt implementation, however, ATI financing is a substantial roadblock and must be transformed.

National governments in the past paid for much of the development, implementation, and sustainment costs of today's ground-based ATI. Political pressures to constrain budgets and reduce deficit spending and related concerns about the creditworthiness of government debt threaten to deprive nations of the ability to pay such costs for future systems. The burden of those costs is shifting to industry.

Aircraft operators will bear more of that burden as a result of technological advances that move the nexus of state-of-the-art CNS/ATM capabilities from ground-based systems owned by governments to airborne systems on operators' fleets. The largest group of operators consists of the world's airlines. They are compelled by operating costs, general economic conditions, and shareholders to judge severely all equipment upgrade proposals. Those that promise swift, significant returns will merit the investment of airlines' limited pools of discretionary funds. Against those criteria, airlines rate many ATI-related investments poorly. The case for such investments is weakened further by the underutilization in today's air traffic control systems of modern airliners' advanced navigation capabilities, which makes those aircraft pricey underperforming assets on an airline's balance sheet.

These financial considerations are critical. In the past, air navigation service providers owned and run by governments dictated CNS/ATM technical requirements aimed at meeting international standards (or adopted those set by the world's largest ANSPs); aircraft operators essentially were compelled to comply and incur related equipment costs to gain access to the skies. Given their new funding role, operators will demand a significant voice in the definition, operation, performance, benefits, and cost of CNS/ATM capabilities. They have clamored for such input in the past, but now they – particularly airlines – hold many of the purse strings. This means airlines control the future ATI investments.

The private sector can close the gaps between funding required to match ATI capabilities with demands of air traffic growth and the inability or unwillingness of governments and operators to provide that funding. Private-sector participation (PSP) in financing infrastructure improvements in roads, rail, ports, prisons, hospitals, and housing is common. It has been widely employed in upgrading airport facilities and operations. Notable successes with ANSPs (both privatized/corporatized and government-owned) have demonstrated PSP's potential for reducing costs to governments, containing costs for operators and making ANSPs more accountable for their performance and efficiency. PSP can help build business cases for ATI investments that align benefits with costs for the gate keeper airlines. The recent global financial environment has left large amounts of cash available for investment in attractively structured deals, and the private-sector firm experienced in aviation and in infrastructure financing can create structures that meet those requirements.

Air Traffic Infrastructure Global Markets 2012 examines these and other market forces that will shape the provision, use, and financing of air navigation services and their infrastructure around the world in the coming decade. The executive summary below reviews those factors and NEXA Advisors' forecasts for the market through 2021.

Analysis of origin-and-destination (O&D) traffic aimed at identifying the 60 countries that present the best prospects for ATI sales and support would produce a list of the usual suspects among the world's largest air markets: the US, China, the UK, Germany, Canada, Spain, and so on. Vietnam would not be high on the list. Bolivia would barely make the cut, and Afghanistan, Jamaica and Tanzania would miss it. But consider their positions under major international routes – between Europe and Asia, South America's Southern Cone and North America, Europe and India, and between Central and South America and much of the world. Combine that with their existing ATI needs and projected growth and you see the significance of such ANSPs come into focus.

We have combined such route analysis with O&D market size, past traffic, and projected growth to compile that list of 60 countries. *Air Traffic Infrastructure Global Markets 2012* assesses the equipment, systems, and services they will require and also identifies the top 50 air traffic infrastructure projects around the world.

Any global study like this must address how to divide the world for analysis and forecasting. For aviation, there is no standard regional division of the world. Industry forecasters, such as those at the major aircraft manufacturers, use divisions that best suit their unique business needs; this presents challenges for firms like NEXA seeking to align different manufacturers' forecasts for analysis.

While the International Civil Aviation Organization (ICAO) sets standards for aviation in many respects, it does not do so for world regions. That agency has consolidated regions in recent years from nine to seven. Their boundaries today reflect ICAO's administrative needs more than geographic groupings. The Caribbean and Central America have been combined with North America into one region, for instance. Africa is split among three, with Algeria, Morocco and Tunisia (as well as the disputed Western Sahara region) assigned to the one that now combines the European and North Atlantic regions.

Unfortunately, ICAO reports and forecasts have not yet been realigned with the new structure, and agency documents often refer to the former nine regions. An additional complication is that ICAO is a United Nations agency and also uses the former's division of six regions for statistical analysis. For this study, we use six regions, which are named and delineated by boundary and composition in Section 6.

1.0 Executive Summary

Increasing air traffic congestion is crowding the world's airspace, resulting in passenger frustration and adverse effects on tourism, business, trade, and the global economy. Despite lingering economic malaise from the 2007 - 2009 recession, and economic and fiscal turmoil in Europe, the International Air Traffic Association (IATA) reports that the first quarter of 2012 saw an 8.1 percent increase in international passenger traffic and a 5.5 percent increase in US traffic. In 2010, there were some 940 million international tourist arrivals worldwide, a 6.6 percent growth over the prior year. ICAO predicts that by 2021 global international air passengers will reach 1.6 billion, and US domestic passengers will number 2.4 billion. To service the growth in passenger traffic as well as increased air cargo, the global commercial aircraft fleet for both passenger aircraft and freighters is projected to grow from 27,000 aircraft in 2011 to 38,000 in 2021.

The first decade of this century was a watershed for ATI throughout the world. Passenger growth and airline movements fluctuated according to regional as well as global political and economic events. As air traffic volumes recover from the latest global recession, congestion and gridlock are again becoming visible.

But aviation infrastructure continues to erode. Governments are broke and must turn to new fees and taxes, and private sources of funding, for infrastructure renewal. Disruptive new technologies and regional differences in the vision of future ATI architectures will challenge the NextGen and SESAR programs. Airlines, coming out of a difficult decade of losses, find that they may foot most of the bill for ATI modernization, whether through investment in avionics or through increased user fees to pay for new ground infrastructure. Airlines are quickly realizing that they are and should be the new gate keepers for ATI modernization.

The ATI market has now reached a strategic crossroad. Several factors have led us here: delayed upgrades — and resulting erosion — of the infrastructure, turmoil in global economies and political systems, the growing level and complexity of air traffic, intensifying environmental concerns, the absence of harmonized visions of the future, lagging application of technological advances, changes to the airline business model, and lackluster airline commitment to CNS/ATM aircraft investment, and more stringent enforcement of international safety standards. Finally, the cost of ATI modernization has gone up, and who will pay for it will define the pace of change. Nothing is what it seems, so over the next 10 years, today's inflection point will take the ATI industry into a new and, we think, highly positive, direction.

1.1 Key Findings

Current ATI modernization initiatives are based on making fuller use of CNS/ATM capabilities on airborne aircraft, such as area navigation (RNAV) and required navigation performance (RNP) approaches, and developing new capabilities like automatic dependent surveillance-broadcast (ADS-B) and digital data-based communications. This is a change from past approaches, which relied largely on ground-based systems paid for, built, and maintained by government-owned/operated ANSPs. That change comes at a time when airlines, the largest and most influential operator group, are increasingly cautious about making investments that provide adequate and timely returns. As a result, airlines will demand a greater voice in the definition of ATI upgrades, the benefits they are intended to provide, the timetable on which they will be provided, and the actual provision of them. Skepticism about ATI-related investments is heightened by past airline investments in ANSP initiatives never brought to fruition and doubts that ANSPs understand the operational constraints of equipping an airline fleet for new capabilities. Airlines will become the gate keepers of ATI modernization initiatives.

1.2 ATI Economics and Policies

The air transport infrastructure sector exhibits all of the characteristics of global integration. Airport and air traffic control systems provide components of the operational environment for the safe and efficient transportation of passengers and goods through the air among sovereign jurisdictions. In and between countries, air transport is an industry driven primarily by domestic and international trade. Thus, the health and efficiency of a nation's air transport sector is often a barometer of that nation's competitiveness.

In addition to generating economic activity with aircraft production, airline operations, airport construction, and CNS/ATM equipment manufacturing, air transport is an integrative tool affecting much of the world's business, as well as a foundation for the tourism industry and a cost-effective means of distributing goods and services. Particular benefits are obtained from a sustained investment in air transport infrastructure because of the impact of this industry on other sectors of the economy, and on the world economy as a whole.

The relationship between efficient air transportation and modern airspace management is well established in developed countries, and is a necessary linkage when considering infrastructure investment in a nation's civil aviation system. Current air traffic infrastructure and air traffic control practices, most of which were developed and implemented more than 60 years ago, are not capable of supporting increased demands for air travel and, in fact, in many nations service is getting worse every year. According to the *Global Competitiveness Report* of the World Economic Forum, in 2008 the US ranked 12th among 134 nations in the quality of ATI. In 2011, it dropped 19 positions, to 31st of 142 nations. A related survey of business executives in 2008 ranked US ATI 6.3 on a scale on which seven represents the world standard. The ranking fell to 5.7 in 2011.

Outdated technology requires large distances between planes for safety and substantial fuel reserves for ATC contingencies that arise from unfavorable clearances, unpredictable weather, or terminal area delays. This, in turn, creates significant costs for the airlines, which lose millions of tons of fuel, and frustrates passengers who miss connections.

Obsolete air traffic control systems also result in headline-making near miss aviation collisions, including one in January 2011 off the coast of New York City in which a military cargo plane almost hit a Boeing 777 with 250 passengers aboard, and another in April of that year that threatened the First Lady, Michelle Obama, when her jet nearly collided with a cargo plane while landing at a US air force base. According to a Washington Post report, some 1,900 ATC slip-ups occur in US airspace annually.

Section 2 deals with environmental policy and ATI. Aviation accounts for only three percent of carbon emissions from the global transport sector, though aviation-related carbon emissions often have a higher warming potential than ones emitted elsewhere. Due to increased fuel savings and lower flight times, modern ATI capable of performing to full potential has the capacity to reduce the carbon footprint of airlines by as much as 15 percent.

Section 2 also examines the global, national, and regional imperatives of the air transport sector and its CNS/ATM infrastructure, with these issues as a backdrop.

1.3 ATI Investment and Financing

Conflicts between funding resources and demand for improved, expanded, and more efficient ATI can be an impetus for change. That was the case in the 1980s, when the UK faced a combination of economic, budgetary and ideological pressures that led to a campaign of privatizing government enterprises. Just a few examples include British Aerospace, British Shipbuilding, British Telecom, British Airways, and eventually National Air Traffic Services.

The resulting trend spread across a variety of government activities in much of the world, including air navigation services, and it continues today.

(Editor's note: A chronology of 60 countries and their evolution toward more business-like models is found in the Appendix).

Other nations have explored more options for reducing the cost and increasing the efficiency of their air navigation services, including reforms intended to allow their ANSPs to operate as a corporation or commercial entity. For example, privatization or contractual commercialization of specific ATI functions can allow a country to reduce air navigation-related costs while avoiding the high hurdle of addressing national security concerns that a wholesale ANSP privatization may provoke. Some nations have turned to the private sector to run all or parts of their ANSP functions, including airspace design, procedures design, training and certification of ATCOs, tower operations, etc., on a contract basis.

The clear solution to government budget constraints is the use of public-private partnerships (PPPs), an arrangement whereby government and private investors share both the risk and profit of infrastructure development. Optimally, investors benefit from steady revenue while the government benefits by providing much needed infrastructure at a far lower cash outlay, freeing up funds to use elsewhere.

Private infrastructure funds pool capital from multiple investors, both foreign and domestic. Their investors include pension funds, sovereign wealth funds, endowments and high-net-worth individuals. While fund governance mechanisms are rarely publicly disclosed, they typically limit the role that a single investor can play to an advisory capacity and minority status, with no rights for operational control of infrastructure assets. What these funds have in common is that they allow quick and easy access to investments in the infrastructure marketplace. They are set up to investigate infrastructure opportunities quickly and efficiently and can commit large amounts of capital in a short timeframe. Investments in infrastructure can be made either indirectly, through a separate fund created to finance a particular infrastructure project, or directly through an equity stake in the project.

As an asset class, ATI projects have attributes historically attractive to investors. These include the long duration of such investments, revenue assurance, inherent protections against volatility and inflation, diversification by geography and business line, relative transparency, and predictability of returns on invested capital due to generally stable cash flows.

In the US, given the huge NextGen price tag and a political climate in which big ticket items will be viewed with a jaundiced eye, a PPP is imperative for aviation modernization and its many tangible benefits for safety, the economy, and the environment. In 2010, ITT Exelis partnered with major aerospace companies to create the NextGen Equipage Fund to begin the equipage process more quickly. The Fund is managed by NEXA Capital Partners, LLC of Washington, DC. The Fund is sizeable ($1.5 billion) and is designed to retrofit up to 70 percent of the US air transport fleet, quickly getting the industry to predominant NextGen equipage levels. It offers low-interest rate financing options that spread the cost of equipage over long periods and defer payments for airlines to better align them with their realization of benefits. The many equipage options are financed from the Fund's equity, supplemented by commercial debt backed by federal loan guarantees.

Section 3 explores the traditional sources of ATI funding initiatives and how increased demand and modernization, coupled with dwindling government funding resources, is quickly leading to a critical gap in funding. The analysis then turns to new sources of capital, such as private sector participation.

1.4 ATI Technologies and Applications

The present air traffic management system has been in use for over 60 years. It was conceived while radar was a nascent technology, and the volume of air traffic was significantly less than today's levels. Repeated attempts to increase capacity in order to meet rising demand in the absence of modern automation or new operational concepts proved to be unsuccessful. Consequently, the flexibility to operate efficiently in global airspace has thus far been inadequately addressed.

In the current air traffic control concept of operation, flight routes and altitude information are provided to airline operators via filed flight plans and positive (radar) control, which often results in significant operational and economic inefficiencies. Flight plans, when used in conjunction with surveillance radar, provide controllers with predictable flight path data for each aircraft in their sector. With this knowledge, controllers are able to manage traffic and resolve potential flight path conflicts. The problem with this concept is that it is highly inflexible and inefficient, particularly as air traffic growth continues to increase.

Trajectory-based operations (TBO) are those airspace operations in which the future trajectories of all aircraft, i.e., their four-dimensional (4D) paths through space and time, are the basis for separation and efficient flow in the airspace. 4D trajectories are predicted and regularly updated by an automation system and used to solve traffic conflicts, satisfy metering constraints, avoid weather and restricted airspace, and find more efficient flight paths, all in an integrated manner.

This shift from clearance-based to trajectory-based air traffic control will enable aircraft to fly negotiated flight paths necessary for full performance-based navigation, taking both operator preferences and optimal airspace system performance into consideration.

Section 4 provides an overview and general discussion of various CNS/ATM technologies and their applications that will be discussed in further detail. Where practical, those technical, operational, and institutional issues that have a direct bearing on the implementation of a specific technology are presented and discussed. Future trends information is also included.

1.5 ATI Supply Chain

Among the most significant aspects of the strategic inflection point reached by the global ATI market – the nexus of this report – is the evolution of well-established and distinct industry supply chains, each having a critical role in ATI modernization.

The global aerospace sector has proven to be a strong and resilient industry segment, even with the shocks of the Great Recession of 2007-2008. Currently the general health of the global A&D sector is good. Since the mid-2000s, the sector has witnessed impressive growth, with the civil aviation segment emerging as the major contributor to this expansion. The US and European countries are the dominant markets for aerospace products, systems, and services, and act as market catalysts supporting this overall growth.

For the purposes of this report, the ATI supply chain refers to the two networks of businesses involved in providing products, systems, and services to customers (Figure 1-1). Included in the section is a composite listing of over 300 companies that contribute to the air traffic industry supply chain and the role played by each.

Figure 1-1

ATI Supply Chain Segment	Top Five Tier 0 Customers
CNS/ATM Ground and Space Systems Supply Chain	• ANSPs • National governments • Airports • Militaries • Aircraft OEMs
CNS/ATM Avionics Supply Chain	• Airlines • Charter and business aircraft operators • Aircraft OEMs • MRO providers • Militaries

1.6 ATI Global Forecasts

In this section, the report integrates the research and analysis of the previous topics to develop investment forecasts for infrastructure and aircraft equipage needed to implement ATI for the ten-year forecast period (2012-2021).

The forecasts project the investment requirements for ANSPs to upgrade or implement programs related to communication, navigation, surveillance (CNS), ATM, automation, weather, facilities, and mission support. Also included is a forecast for necessary CNS avionics equipage investment across the global fleet. These ATI market forecasts project estimates based on what world governments and commercial aircraft operators need to procure over the next decade to keep pace with emerging ATI modernization requirements.

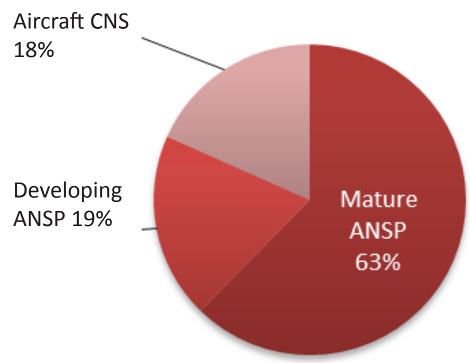
Transitioning air traffic control and management to next-generation infrastructure and the supporting systems is very costly. Therefore, budgetary constraints restrict what and where a nation can afford to invest. The forecasts analyze the gap between requirements and constraints due to the shortage of capital. Therefore, we present the ATI forecasts via two perspectives:

- Unconstrained by availability of capital – assuming no project funding restrictions exist.
- Constrained by availability of capital – applying funding constraints by country and region of the world.

Taken together, the Study Team projects that over the next decade the six regions and respective airlines of the world will face an unconstrained investment requirement of US$105 billion for ground and airborne systems to transition to a global satellite-based CNS/ATM infrastructure (Figure 1-2).

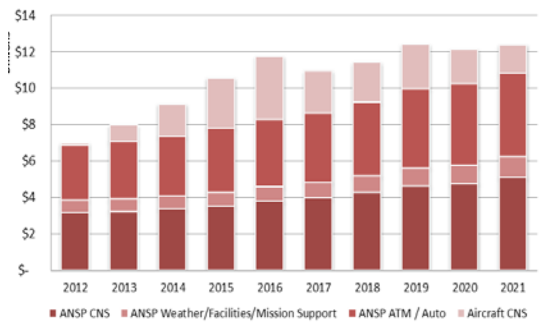
Communication, navigation, and surveillance capabilities account for $39 billion (38 percent) of the anticipated ATI investment. The projected ANSP unconstrained investment requirement for ATM/Automation over the next decade exceeds $37 billion, or 36 percent of the required ATI investment. The other ATI investment requirement categories are weather systems, facilities, and mission support. Collectively, they will require $8 billion (Figure 1-3).

Figure 1-2
Mature ANSP, Developing ANSP, and Aircraft Investment



Source: NEXA Forecast

Figure 1-3
Annual ATI Investment



Source: NEXA Forecast

The Study Team also segmented the unconstrained global ANSP investment requirement into three functions: equipment, systems, and services.

- Equipment upgrade and replacement is projected to require $33 billion through 2021 (39 percent of the total ATI investment requirement). Infrastructure consists of basic hardware to support ATI modernization and sustainment programs, including ADS-B ground stations, runway lighting, and equipment to support GPS, WAAS, EGNOS, PBN, RNAV, and RNP procedures.
- Systems that make the hardware function are projected to require a $46 billion (55 percent of total ATI) investment

by ANSPs over the next decade. These systems include trajectory-based operations that allow for more direct flight paths, collaborative air traffic management and decision-making, and improved traffic flow management systems.

- Services are projected to require an unconstrained investment by ANSPs of $5 billion (six percent of total ATI) over the next decade; these include training, weather services, system engineering, research, and development. The mature ANSPs will invest heavily in systems engineering and R&D programs, while the developing ANSPs are more likely to purchase off-the-shelf solutions and focus on training support programs.

The aircraft equipage forecasts detail the investments required for airlines to take advantage of advanced CNS and ATM programs. The forecasts estimate commercial aircraft equipage investment by aircraft type (twin-aisle, single-aisle, regional jet, and turboprop), by program (communications, navigation, and surveillance), and by world region (North America, Europe, Asia Pacific, Middle East, Africa, and Latin America).

The ATI investment required of commercial airlines through 2021 will follow the ANSP investment profile. More than $19 billion, or 18 percent of the total unconstrained ATI investment forecast, will be required by airlines to install avionics such as ADS-B, satellite-based navigation, and digital communications.

According to an analysis of the financial health of both government and airlines, immediate and persistent investment constraints could produce a shortfall of $26 billion, representing approximately 25 percent of the investment requirement over the next decade. Unfortunately, much of the gap could go unfunded, leaving ATI programs behind demand for the services, and delayed and inadequately funded over the next decade. Therefore, closing this funding gap will require greater utilization of alternative funding sources, including the private sector. This gives rise to new opportunities for companies to structure financing when pursuing these.

1.7 ATI Airline Business Case

Section 7 focuses on the unique business case challenges faced by the airlines as they confront the prospect of investing in, and waiting for, the benefits promised by the new globally-integrated air traffic management system.

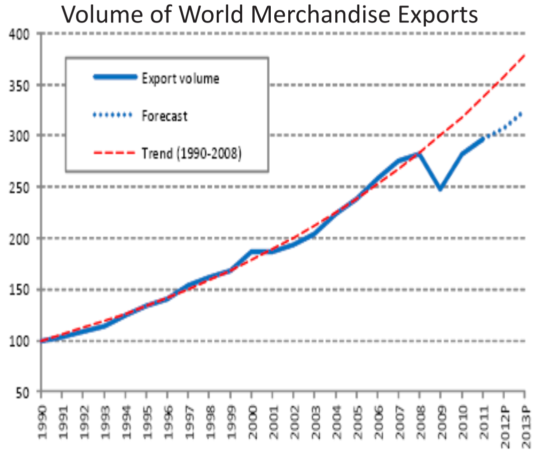
2.0 ATI - A Global Economic and Policy Perspective

The world's economies are becoming increasingly integrated and interdependent. Examination of the automotive, computer, or chemical industries point to operations that integrate factory processes and supply chains that span six continents. One nation's trade, commerce, and environmental programs in turn affect the entire world community. Industrialization, advanced transportation, globalization, multinational corporations, and outsourcing are all having a major impact on the international trade system. Increasing international trade is crucial to the continuance of globalization. Without international trade, nations would be limited to the goods and services produced within their own borders.

This section examines the global, national, and regional imperatives of the air transport sector and its CNS/ATM infrastructure.

Figure 2-1

Volume of World Merchandise Exports



Source: World Trade Organization

2.1 The Economics of ATI

Over $27 trillion in annual trade occurs (2011 estimate by the International Trade Center) among sovereign borders of the world. Growth in trade continues, as illustrated in Figure 2-1, even after the effects of the Great Recession of 2008-2009.

Global tourism is also relevant to ATI and, in some cases, vital for many countries. It brings in large amounts of income in payment for goods and services available, contributing an estimated five percent to the worldwide gross domestic product (GDP), and it creates opportunities for employment in the service industries associated with tourism. In 2010, the last full year for which numbers are available, there were over 940 million international tourist arrivals worldwide, representing a growth of 6.6 percent compared to 2009. International tourism receipts grew to $920 billion in 2010, an increase in real terms of 4.7 percent.

The air transport industry exhibits all of the characteristics of global integration. Airport and air traffic control systems provide components of the operational environment for the safe and efficient transportation of passengers and goods through the air among sovereign jurisdictions. In and among countries, air transport is an industry driven primarily by domestic and international trade. Thus, the health and efficiency of a nation's air transport sector is often a barometer of that nation's competitiveness.

In addition to generating economic activity with aircraft production, airline operations, airport construction, and CNS/ATM equipment manufacturing, air transport is an integrative tool affecting much of the world's business, as well as a foundation for the tourism industry and a cost-effective means of distributing goods and services. Particular benefits are obtained from a sustained investment in air transport infrastructure because of the impact of this industry on other sectors of the economy, and on the world economy as a whole.

The relationship between efficient air transportation and modern airspace management is well established in developed countries, and is a necessary linkage when considering infrastructure investment in a nation's civil aviation system.

In the early 1980s, civil aviation authorities recognized the increasing limitations of ground-based communications, navigation, and surveillance systems comprising the ATC systems of the time. New emerging CNS technologies offer the CAAs an opportunity to support new CNS/ATM operations concepts that could not otherwise be cost-effectively implemented.

The need to overcome the limitations of terrestrial-based CNS systems is driven by economic and institutional imperatives. Developing and implementing the new CNS/ATM systems requires technological innovation as well as investment in restructuring most traditional aviation roles and relationships among nations. Therefore, states must carefully analyze and balance the complex linkages between:

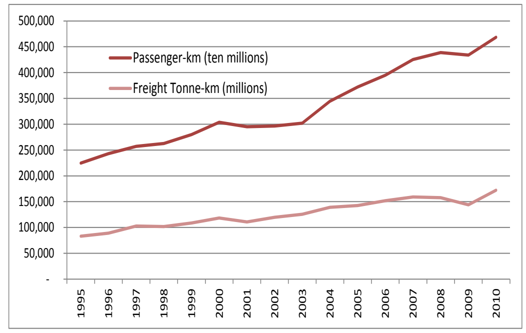
- The requirements for modern CNS/ATM infrastructure, driven by safety and other considerations perhaps social or political in nature.
- The limiting reality of economic resources.
- Forces driving international competition to sustain competitive advantage in the dynamic global market environment.

GDP Growth

The air transport industry has for many years experienced greater growth than most other industries. Figure 2-2 highlights the historically documented growth of passenger, freight, and air mail transport during the past five decades. This is a direct result of demand for air transport being primarily driven by economic development and trade. Increasing demand for passenger and freight services, rapid technological development, and associated investment have combined to multiply the output of the industry by a factor of about 75 since 1950 (in terms of tonne-kilometers performed). To put this into perspective, the total world GDP, which is the broadest available measure of world output, has multiplied by less than six times over the same period.

Figure 2-2

Historical World Passenger and Freight km Performed



Source: ICAO

While the escalation in air traffic has been much greater than growth in national economies, economic theories and studies such as this indicate that the high correlation between the two is primarily determined by two distinct elements of economic development:

- Commercial activity and trade have a direct impact on the demand for business travel and air freight.
- Developments in personal income affect the level of consumer purchasing power and the propensity to undertake leisure travel.

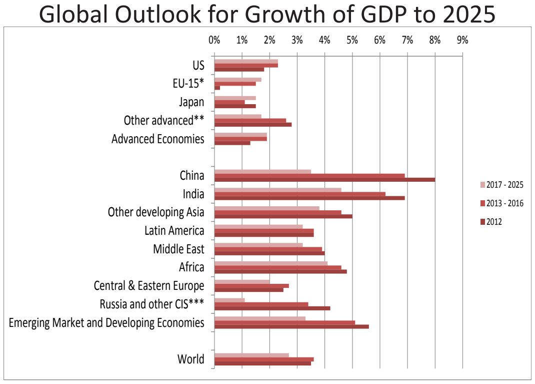
Other factors which have affected traffic demand include changes in airline costs, which directly affect airfares and cargo rates, availability of air services, regulatory developments, and tourism.

Relentless advances in new technology have had a dramatic impact upon demand, a fact that will become even more evident during the next 20 years. Rapid passenger travel growth in the 1960s coincided with the replacement of piston-engine aircraft with jet aircraft, which in turn led to reduced real fares and increased speed (convenience and utility), and improvements in the comfort of travel. Limitations are being reached in air capacity, and new ATC equipment and procedures will be able to deal with this challenge (the topic of this report).

Higher oil prices in the last decade have had a restraining effect upon traffic demand that continues today. The ten-fold increase in jet fuel prices on the world markets since the 1970s has greatly increased operating costs and hence ticket prices for travel and fees for air cargo. Through 2010 (and continuing throughout the middle of 2012) GDP in advanced economies grew by an estimated 1-1.5 percent in real terms, as shown in Figure 2-3. ICAO regions varied dramatically in their economic performance. Asia Pacific regions led the world in growth.

Figure 2-3

Global Outlook for Growth of GDP to 2025



Source: The Conference Board

According to a 2012 Conference Board report, until at least the middle of the next decade, global growth is likely to slow. A recovery in advanced economies will be more than offset by a gradual slowdown in emerging ones as they mature, with the net result that global growth will slow. But the biggest risk ahead for the global economy is not this slower overall growth in output but a slowdown in average output per capita, which will determine how fast living standards can be supported and raised.

Global growth is projected to increase to 3.5 percent in 2012, accelerate somewhat to 3.6 percent from 2013-2016, and then show a further slowdown to 2.7 percent from 2017-2025. At three percent, on average, global growth will still be somewhat higher than the period 1980-1995 but between half and a full percentage point below the growth rate from 1995-2008.

Advanced economic growth is expected to slow down from an already meager 1.6 percent in 2011 to 1.3 percent in 2012. For 2013-2016, the outlook suggests some recovery in advanced economies, bringing these countries back to the pre-recession growth trend of a little more than two percent.

In 2012, emerging economies will slow in growth by 0.7 percent on average, dropping from 6.3 percent growth in 2011 to 5.6 percent in 2012, partly as a result of slower export growth and partly because several have been growing above trend. From 2017-2025, emerging and developing countries are projected to grow at 3.3 percent. Many economies will begin to show signs of maturing, at which point the rapid catch-up growth abates.

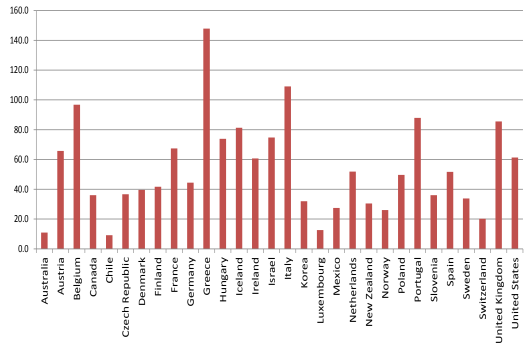
The greatest challenge for the global economy in this slow-growth environment is to raise productivity without losing job opportunities for the millions who are looking for reasonably paid jobs to support their living standards. The global growth rate of per capita income has been around 2.5 percent since the beginning of the current century, but sometime between 2017 and 2025 this rate is expected to fall below two percent. In contrast to the last half century, that slowdown will also be accompanied by slower population growth.

External Debt and Trends

Investment in ATI and supporting infrastructure (e.g., airports, roads, etc.) is critical to continuing growth in trade, which further accelerates demand for air transport. External debt associated with infrastructure investments in developing countries accounts for some 35 percent of total debt, with the remaining 65 percent in education, environment, and consumption. The total debt of all developing countries, including short-term debt, was estimated at about 100 percent of GDP, as shown in Figure 2-4.

Figure 2-4

Total Debt to GDP



Source: OECD

As will be discussed in later sections, the most difficult issue facing governments in modernizing infrastructure, of which CNS/ATM systems comprise an element, arises from the need to find sources of capital. Extreme debt loads are driving the governments of developed, developing, and emerging nations to consider the most practical recourse for their ANSPs, such as public-private partnerships, corporatization, and even privatization. The largest single air traffic control organization in the world, the FAA, is under such scrutiny. Having once rejected the concept, the US government is beginning to reconsider corporatization of the FAA (work on this was last seriously undertaken in the 1990s) in order to streamline and bring further into line the fiscal challenges of managing, financing, and modernizing its ATC infrastructure.

Key Points:

- Enormous pressures will remain for governments and ANSPs to invest in ATI modernization.
- Pressures will increase as congestion and other problems exact costs on trade and commerce, and on stakeholder industries such as manufacturing.
- As countries and regions refine their economic policies to improve their competitive positions, higher priority will be given to ATI.
- Companies competing for ATI business will increase their market advantage through implicit recognition of the economic challenges facing their customers, and offer solutions that can overcome technical, financial and policy barriers.

2.1.1 Airport Infrastructure

An estimated 47,800 airports provided domestic and military service globally as of January 2012. Of these, 6,977 airports accepted commercial traffic spanning the globe.

Most airports are owned by local, regional, or national government bodies that sometimes lease them to private corporations that oversee operations. For example, BAA Limited operates seven of the commercial airports in the UK, as well as several other airports outside of the UK. Germany's Frankfurt Airport is managed by the quasi-private firm Fraport. In India, GMR Group operates, through joint ventures, Indira Gandhi International Airport and Rajiv Gandhi International Airport. The GVK Group controls Bengaluru International Airport and Chhatrapati Shivaji International Airport. The rest of India's airports are managed by the Airports Authority of India.

In the US, commercial airports are generally operated directly by government entities or government-created airport authorities (also known as port authorities), such as the Los Angeles World Airports authority that oversees several airports in the greater Los Angeles area, including Los Angeles International Airport.

In Canada, the federal authority Transport Canada divested itself of all but the remotest airports by 2000. Now, most airports in Canada are owned and operated by individual legal authorities or are municipally owned.

Some US airports lease part or all of their facilities to outside firms, which operate functions such as retail management and parking. In the US, all commercial airport runways are certified by the FAA under the Code of Federal Regulations Title 14 Part 139, "Certification of Commercial Service Airports" but are maintained by the local airport under the regulatory authority of the FAA.

Despite the reluctance to privatize airports in the US (although the FAA has sponsored a privatization program since 1996), the government-owned, contractor-operated (GOCO) arrangement is a popular standard for the operation of commercial airports in the rest of the world. Some of the largest airports in the world can be benchmarked using international and domestic passenger embarkations as a measure.

Figure 2-5

Top 30 Airports by Movements for year ending Jan. 2012

Airport	Total
ATLANTA GA, US(ATL)	930,260
CHICAGO IL, US(ORD)	878,465
DALLAS/FORT WORTH TX, US(DFW)	645,124
DENVER CO, US(DEN)	620,278
LOS ANGELES CA, US(LAX)	611,401
CHARLOTTE NC, US(CLT)	543,818
BEIJING, CN(PEK)	540,114
LAS VEGAS NV, US(LAS)	535,742
HOUSTON TX, US(IAH)	528,385
PARIS, FR(CDG)	510,237
FRANKFURT, DE(FRA)	485,020
LONDON, GB(LHR)	480,503
PHOENIX AZ, US(PHX)	461,335
PHILADELPHIA PA, US(PHL)	448,614
AMSTERDAM, NL(AMS)	440,327
DETROIT MI, US(DTW)	439,839
MINNEAPOLIS MN, US(MSP)	431,254
TORONTO ON, CA(YYZ)	430,988
SAN FRANCISCO CA, US(SFO)	412,302
NEWARK NJ, US(EWR)	412,085
MADRID, ES(MAD)	411,070
MUNICH, DE(MUC)	406,979
NEW YORK NY, US(JFK)	406,875
MIAMI FL, US(MIA)	397,885
TOKYO, JP(HND)	385,222
BOSTON MA, US(BOS)	369,351
NEW YORK NY, US(LGA)	365,591
MEXICO CITY, MX(MEX)	363,423
GUANGZHOU, CN(CAN)	357,890
JAKARTA, ID(CGK)	356,252

Source: Airports Council International

Along this dimension, the 25 busiest airports handle a total of 700 million passengers, or about 30 percent of the world total of scheduled and non-scheduled passengers. The heaviest concentration of traffic is found at 17 US airports, ranking by passenger embarkations.

There are significant differences between the rankings of airports by passengers and by movements. For example, Tokyo Haneda ranks fourth in terms of passengers handled, but 36th in terms of aircraft movements. This difference illustrates the heavy orientation of these airports to wide- bodied aircraft.

The world's busiest airports by movements are listed in Figure 2-5. To expand capacity, including new runways, gates, and passenger capacity, two classes of airport projects are underway. In the last 10-15 years, new international airports have opened at less than 20 locations worldwide. Major airport expansions are underway in all regions of the world. In fact, many airports are in a constant stage of renewal and upgrading.

Future growth in civil aviation capacity via airport expansion will take place in an atmosphere of increasing public concern regarding the environment. Until recently, the most important environmental problem associated with civil aviation was aircraft noise. Noise levels near airports are subject to two opposing trends: quieter aircraft and increasing traffic. The noise issue requires months of environmental impact studies, and in some countries can waylay development of new runways or expansion of existing terminals for years.

Estimates of construction costs for global airport work over the next ten years run into the hundreds of billions of dollars. This is due to the costly orientation of such projects toward real-property transactions, and the need for airport runways and facilities to be strategically located near population centers. However, environmental concerns create new hurdles that make even existing airport expansion costly.

2.1.2.1 Airport Revenues

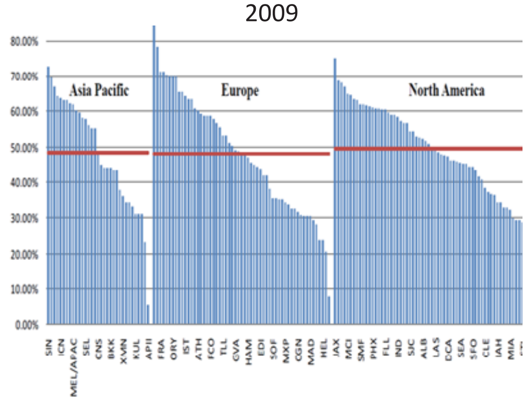
Airports around the world have a role in financing and provisioning ATI infrastructure. About 35 percent of airports outside the major economies have responsibility for ATI for aircraft takeoffs, landings and, from time to time, overflights. In the US, the ATI mandate is largely federal, and the FAA must provision CNS/ATM, but many US airports enhance their operations and aircraft movements by separately financing a range of CNS/ATM ground systems, including landing systems, lighting systems, navigation, and ADS-B (Automatic Dependent Surveillance Broadcast) facilities.

Many different types of financing are available for airport construction or expansion, and local laws and practices usually apply. Capital projects are almost always financed through collection (and sometimes securitization) of landing fees and airport improvement fees (e.g. PFCs), as well as cash flows from other airport operations-related revenues (e.g. parking or concession fees).

There may be a correlation between the amount of traffic an airport can manage and its fees, based on the assumption that a larger airport can handle more traffic and thus spread the total airport maintenance and operating costs out over more carriers, as well as being able to generate more revenues from concessions, retail, parking, and other services. Figure 2-6 shows that non-aviation revenues can account for as much as 85 percent of total revenues.

Figure 2-6

Percent of Non-Aviation Revenues by Airport in 2009



Source: Air Transport Research Society

Landing Fees

A landing fee is a charge paid by an aircraft operator or airline to an airport company for landing at a particular airport. Landing fees can vary greatly among airports, with the largest fees paid at congested airports, ones where most of the landing slots are held by airlines, while less congested airports charge less because of lower demand. The money generated by landing fees is used to pay for the maintenance or expansion of the airport's buildings, runways, aprons, and taxiways.

Strategically set lower landing fees can attract more flights. Some airports, especially general aviation (GA) airports, do not charge landing fees.

Landing fees may encompass additional airport-provided services. Some airports will simply charge a single fee for landing and provide gates and check-in facilities as part of that fee. Other airports will charge a lower fee for landing but will charge airlines for the use of gates and check-in facilities.

Landing fees cannot easily be compared as they are affected by a wide range of factors. For example, many airports in the US receive subsidies from the FAA, while airports in other countries do not. Fees can be based on any number of factors including:

- Aircraft weight.
- Number of seats.
- Time of day.
- Aircraft home airport. (Some airports do not charge fees for aircraft based at that airport or offer a lower fee for them.)
- Operator class. (Some airports may charge a fee for specific types of operators, like commercial air carriers, but not other aircraft operators, such as general aviation.)

Airport Improvement Fees

An airport improvement fee, embarkation fee, airport tax, service charge, or service fee is an additional fee charged to departing and/or connecting passengers at an airport. It is levied by a government or an airport management corporation, and the proceeds are usually intended for funding major airport improvements or expanding airport service. Some airports do not levy these fees on connecting passengers who do not leave the airport or whose connecting flight is within a specific timeframe after they arrive. Depending on the location, the airport improvement fee is included in the cost of a passenger's airline ticket, in which case the airline will forward the fee to the proper entity. A small sample of airports currently collecting an explicit airport improvement fee includes:

- Jorge Chavez International Airport Lima, Peru.
- Ministro Pistarini International Airport (Ezeiza), Buenos Aires, Argentina.
- Ramón Villeda Morales International Airport San Pedro Sula, Honduras.
- Ngurah Rai Airport (Denpasar), Bali, Indonesia.
- Indira Gandhi International Airport New Delhi, India.
- Soekarno-Hatta International Airport Jakarta, Indonesia.
- Carrasco International Airport, Montevideo, Uruguay.
- Norwich International Airport, Norwich, United Kingdom.
- Newquay Cornwall Airport, Newquay, United Kingdom.
- Ireland West Airport Knock, Knock, Republic of Ireland.
- Ninoy Aquino International Airport, Manila, Philippines.
- Almost all Canadian international airports.
- Almost all Brazilian airports administered by Infraero.
- All airports in China.

2.1.2.2 Airport Project Financing

Airport project finance is the long-term financing of infrastructure and industrial projects based upon the projected cash flows of the project rather than the balance sheets of the project sponsors. Usually, a project financing structure involves a number of equity investors, known as sponsors, as well as a syndicate of banks or other lending institutions that provide loans to the operation. The loans are most commonly non-recourse loans, which are secured by the project assets and paid entirely from airport-produced revenues and cash flow, rather than from the general assets or creditworthiness of the project sponsors, a decision in part supported by financial modeling. The financing is typically secured by all of the project assets, including revenue-producing contracts. Project lenders are given a lien on all of these assets and are able to assume control of a project if the project management company has difficulties complying with the loan terms.

Generally, a special purpose entity is created for each project, thereby shielding other assets owned by a project sponsor from the detrimental effects of a project failure. As a special purpose entity, the project company has no assets other than the project. Capital contribution commitments by the owners of the project company are sometimes necessary to ensure that the project is financially sound or to assure the lenders of the sponsors' commitment. Project finance is often more complicated than alternative financing methods. Traditionally, project financing has been most commonly used in the extractive (mining), transportation, telecommunications, and energy industries.

More recently, particularly in Europe, project financing principles have been applied to other types of public infrastructure under public–private partnerships (PPP) or, in the UK, a pioneer in this new method, private finance initiative (PFI) transactions (e.g., for school facilities, as well as sports and entertainment venues.)

Risk identification and allocation is a key component of airport project finance. A project may be subject to a number of technical, environmental, economic, and political risks, particularly in developing countries and emerging markets. Financial institutions and project sponsors may conclude that the risks inherent in project development and operation are unacceptable (unfinanceable). To cope with these risks, project sponsors in these industries are generally completed by a number of specialist companies operating in a contractual network with one another that allocates risk in a way that allows financing to take place. Several long-term contracts such as construction, supply, off-take, and concession agreements, along with a variety of joint-ownership structures, are used to align incentives and deter opportunistic behavior by any party involved in the project. The various patterns of implementation are sometimes referred to as "project delivery methods." The financing of these projects must also be distributed among multiple parties, so as to distribute the risk associated with the project while simultaneously ensuring profits for each party involved.

A riskier or more expensive project may require limited recourse financing secured by a surety from sponsors. A complex project finance structure may incorporate corporate finance, securitization, derivatives, insurance or other types of collateral enhancement to mitigate unallocated risk.

Airport project finance shares many characteristics with maritime finance and aircraft finance; however, the latter two are more specialized fields within the area of asset finance. More is said on this topic expressly regarding air traffic infrastructure finance in Section 3 of this report.

2.1.2 ANSPs and Finances

An ANSP is an organization that is vested in legal and regulatory authority to separate aircraft on the ground or in flight in a dedicated block of airspace, on behalf of a state or a number of states. ANSPs are government departments, state-owned companies, or privatized organizations.

CANSO

The majority of the world's ANSPs are members of the Civil Air Navigation Services Organization (CANSO), a group with increasing influence in policy setting and harmonization matters. CANSO has become the global voice of the companies and agencies that provide air traffic control, and represents the interests of air navigation service providers worldwide. CANSO members are responsible for supporting 85 percent of world air traffic and, through various workgroups, members share information and develop new policies, with the ultimate aim of improving navigation in the air and on the ground. CANSO also represents its members' views in major regulatory and industry forums, including at ICAO, where it has official observer status. CANSO seeks to:

- Maintain an international forum for the development and exchange of ideas on current ATM-related issues and the formation of distinct policies and positions.
- Develop an international network for ANS experts to enable further information exchange between specific ANSPs and other stakeholders for the promotion of best practice within ATM.
- Liaise with other transport industry stakeholders, particularly the airlines, industry suppliers, and airports, to the overall benefit of the aviation industry.
- Contribute to the continuous global air transport debate through the presentation and promotion of the ANSP perspective across the range of contemporary issues in the industry.
- Represent the views and interests of members at relevant international institutions, particularly ICAO.
- Promote and support international legislation, regulations, and agreements that strengthen the position of members.

Figure 2-7

Current CANSO Members by Category Type

Category 1	Category 2 (Require Non-representation Clause)
Aena	ANWS
AEROTHAI	Aeroportos de Moçambique, E.P.
Airport & Aviation Services (S.L.) Ltd (AASL)	CAAS
Airports Authority of India	DCA Cyprus
Airservices Australia	DECEA
Airways New Zealand	FAA
ANS of the Czech Republic	GACA
ATNS	GCAA
Austro Control	Hellenic Civil Aviation Authority
Avinor	Luxembourg ANA
AZANS	Maldives Airports Co. Ltd
Belgocontrol	SENEAM
BULATSA	State ATM Corporation
CAA Uganda	Civil Aviation Authority of Bangladesh (CAAB)
CARC	Kenya Civil Aviation Authority
DFS Deutsche Flugsicherung GmbH	U.S. DoD Policy Board on Federal Aviation
DHMI	
DSNA	
EANS	
ENAV S.p.A.	
Finavia Corporation	
HungaroControl Pte. Ltd. Co.	
Irish Aviation Authority	
ISAVIA Ltd	
Kazaeronavigatsia	
LFV	
LGS	
LPS SR, š.p.	
LVNL	
MATS	
MoldATSA	
NAATC	
NAMA	
NANSC	
NATA	
National Airports Corporation Limited	
NATS	
NAV CANADA	
NAV Portugal	
Naviair	
OACA	
Oro Navigacija	
PANSA	
PNG Air Services Ltd	
Prishtina International Airport J.S.C.	
PT Angkasa Pura II (Persero)	
ROMATSA	
Sakaeronavigatsia Ltd	
Serco	
skyguide	
Slovenia Control	
SMATSA	
UkSATSE	
Angkasa Pura I	
Israel Airports Authority	
Tanzania Civil Aviation Authority	
Dirección General de Control de Tránsito Aéreo (DGCTA)	

Source: CANSO

CANSO has a number of standing committees and workgroups which deliver policy and set standards on behalf of the members. They bring together global experts to address issues of common interest, to exchange experience for the promotion of best practice, and to develop specific policies across a broad spectrum of issues. Standards committees and workgroups include:

- **The Operations Standing Committee (OSC):** Airspace Services Harmonization; AIS-AIM; Operational Performance Metrics; Collaborative Airspace; and Environment.

- **Policy Standing Committee:** Bench-marking; Global Benchmarking; Human Resources; and Quality Management.

- **Safety Standing Committee:** Future SMS Development; Operational Safety; Safety Performance Measurement; and SMS Capability.

Full membership is open to all ANSPs regardless of their legal status, including ANSPs that are integrated within government structures and departments. Members not separated from their governments are able to sign an article of membership which explicitly recognizes that CANSO does not represent the national government of the ANSP's home state in any way (Figure 2-7).

The associate membership of CANSO is drawn from a wide range of companies and organizations across the entire aviation industry involved in the delivery of air traffic services. Membership offers them the chance to network both formally and informally with clients and key decision- makers across the aviation industry. Associate members are also encouraged to lend their expertise to CANSO's work programs and help it to continue improving the delivery of air navigation services.

2.1.3.1 ANSP Revenues

ANSP revenues are set by policies whose specific rates and charges are determined through a myriad of stakeholder inputs, as well as governance or approval processes. ANSPs are pressured to charge fees in a uniform manner.

ICAO guidelines for ANSP charges and fees are often cited when examining such costs to airlines and others. ICAO's *Policies on Charges for Airports and Air Navigation Services,* which follows, contains the recommendations and conclusions of the council resulting from ICAO's continuing study of charges in relation to the economic situation of airports and air navigation services provided for international civil aviation. The policies are intended for the guidance of contracting states and are non-binding.

Cost Basis

ICAO considers that, as a general principle, where air navigation services are provided for international use the providers may require the users to pay their share of the related costs; at the same time, international civil aviation should not be asked to meet costs which are not properly allocable to it. ICAO encourages its member states to maintain accounts for the air navigation services they provide in a manner which ensures that air navigation services charges levied on international civil aviation are properly cost based.

ICAO also recommends that when establishing the cost basis for air navigation services charges, the following principles should be applied

- The cost to be shared is the full cost of providing the air navigation services, including appropriate amounts for cost of capital and depreciation of assets, as well as the costs of maintenance, operation, management, and administration.

- The costs to be taken into account should be those assessed in relation to the facilities and services, including satellite services, provided for and implemented under the ICAO *Regional Air Navigation Plan(s)*, supplemented where necessary pursuant to recommendations made by the relevant ICAO Regional Air Navigation Meeting.

Much more can be found on the policy side by studying ICAO's *Policies on Charges for Airports and Air Navigation Services*. In practice, ANSPs and umbrella organizations managing the affairs of some of them seem not to have a uniform approach to cost-based charging, claiming instead that they adhere to the spirit of the "voluntary" ICAO guidelines.

We discuss several examples here to bring details to light. More information, by country, can be found in the appendix to this report.

France: DSNA – Direction des services de la navigation aerienne

- **Organization:** Government agency, 7,618 employees, 4,113 controllers, established in March 2005. Revenue: €1.2 billion ($1.47 billion.)

- **Governance:** DSNA and the Civil Aviation Authority (DGAC) fall under the Ministry of Transport. As a result of the change of the air navigation department (DNA) to the air navigation services department (DSNA), DSNA is focused on air navigation services and no longer has responsibility for regulations. The Strategic and Technical Affairs Department of the Ministry (DAST) has assumed this role.

- **Fee Structure:** Two types of charges are levied on air navigation users: route charges and terminal charges. Route charges represent remuneration for the use of facilities and services, implemented by France above metropolitan areas and their vicinity, for en route air traffic and movements, including radio communications and meteorological services. Charges are calculated and collected by EUROCONTROL based on multilateral route charge agreements. The terminal charges are due at the time of each take-off from an airport belonging to the field of application of the terminal charges. The French unit charge is lower than the EUROCONTROL average and below most rates of comparable European countries. Terminal service charges have recently increased.

Germany: German Air Traffic Control (DFS)

- **Organization:** Public-private partnership. 5,400 employees, 2,098 controllers. Privatized in 1993. Revenue: €923 million ($1.13 billion).

- **Governance:** Governed by board of managing directors consisting of three executives. A supervisory board of six employees and six representatives from other ministries oversees management and represents employee interests. Regulatory oversight is a government affair, while DFS has operational responsibility. Transport Ministry reviews and approves any changes in user fees and has an independent economic regulatory authority to comply with the requirements of the forthcoming Single European Sky initiative.

- **Fee Structure:** Funded through user fees from aircraft operators and revenue from aeronautical information services and consulting services. EUROCONTROL collects en route charges on behalf of contracting states for en route air navigation services and facilities which are used by aircraft in the airspace of the flight information regions of Germany. Overdue charges are subject to interest on late payment and recovery enforcement measures. DFS bills and collects terminal charges for services and facilities for aircraft during take-off and landing at German airports. The charge is immediately due. If payment is delayed by more than one month, a penalty charge may be added.

United Kingdom: UK NATS

- **Organization:** PPP was established in 2001 with the following ownership: 49 percent government, 5 percent NATS staff, 42 percent airline, and 4 percent Airport Authority. 3,758 employees, 1,380 controllers. Privatized 2001. Revenue: £599 million ($940 million.)

- **Governance:** NATS has a board of directors, in which there are representatives of each group that holds an ownership interest, as well as the public. CAA exercises economic regulation over NATS.

- **Fee Structure:** Fees are calculated based on chargeable service units (CSU), calculated from the distance flown by an aircraft in controlled airspace and its weight. Recently, NATS charged £48.47 ($76.06) per CSU. All other European air traffic service providers use the same formula to determine their charges to airspace users.

Canada: NAV CANADA

- **Organization:** Privately-owned company, 5,400 employees, 2,300 controllers. Privatized 1996. Revenue: C$1 billion ($996 million).

- **Governance:** Governed by a 15-member board of directors consisting of representatives from airlines (4), government (3), unions (2), business and general aviation (1), independent stakeholders (4), and president and CEO of NAV CANADA (1). The Canadian Transport Agency (CTA) reviews the price-setting process against an established set of principles. NAV CANADA is legislatively required to place all revenues in excess of costs in its rate stabilization fund.

- **Fee Structure:** Funded solely through air navigation fees levied on aircraft operators. NAV CANADA charges are based on the use of metric units and have two components: 1) base rate — set to meet the corporation's annual financial requirements; and 2) variable rate — mechanism used to recover prior period shortfalls or return prior period surpluses. A fee structure is in place to collect: daily, quarterly, annual fees; en route charges; oceanic charges; extra services charges; and terminal service fees.

Australia: Airservices Australia

- **Organization**: Government-owned company. 2,900 employees and 1,100 controllers. Corporatized 1988. Revenue: A$900 million ($944 million).

- **Governance:** Governed by a board of directors appointed by the Minister for Transport and Regional Services. The board is responsible for deciding the objectives, strategies, and policies to be followed by Airservices and ensuring that Airservices performs its functions in a proper, efficient, and effective manner. The board appoints a CEO. The Australian Competition and Consumer Commission (ACCC), an independent commonwealth authority, oversees the process of setting user fees for air traffic services and decides to accept or reject proposed price changes.

- **Fee Structure:** Airservices' new five-year, long-term pricing agreement for en route, terminal navigation, and aviation rescue and firefighting services was effective in October 2011. The agreement offers price certainty to industry and follows industry consultation and review by the Australian Competition and Consumer Commission (ACCC).

2.1.3 ATI Economic Drivers

In September 1991 at the 10th ICAO Air Navigation Conference held in Montreal, ICAO members acknowledged that growth in air commerce, coupled with advancement in technology, is forcing a shift from regional to global means for CNS. The conferees agreed on the need for global coverage, digital air-to-ground data interchange, and non-precision navigation/approach services, concluding that satellite-based CNS systems will likely be the key to worldwide improvements. Eighty-five nations initiated planning for the transition to a common global CNS/ATM system. The parties agreed on the need, vision, and technical approach concerning the future air navigation system.

The reality is that payment for and transition and integration to/of new systems are the most difficult institutional problems facing CNS/ATM system designers and program managers. Many of the details are driven by regulatory, bureaucratic, and even trade considerations. Below are some of the more prominent issues being considered.

2.1.4.1 Pressures and Pace of Change in Global Trade

In the last two decades, increased globalization and intensified competition in world trade has resulted not only from the liberalization of trade policies in many countries, but also from major technological advances in communications, transportation systems, etc. These developments have transformed the traditional organization of production and marketing to focus on the management of logistics to achieve cost savings in inventory and working capital and permit a timely and appropriate response to changing consumer demands.

As the world's economies become more closely integrated, dependency on travel and communications will also grow. Acceleration of these trends through regional trading alliances began with the 1992 European Commission, the 1993 North America Free Trade Agreement (NAFTA), the 1995 World Trade Organization (WTO), and others. A trade pact is a wide-ranging tax, tariff, and trade agreement that often includes investment guarantees. The most common trade pacts are of the preferential and free trade types concluded to reduce (or eliminate) tariffs, quotas, and other trade restrictions on items traded among the signatories. Through these and several pending regional trade agreements, the reliance upon air transport increases in measurable amounts. Whether these increases in air services are sustainable is a matter for review later in this study.

The purpose of the World Trade Organization is to supervise and liberalize international trade. The organization officially commenced on January 1995 under the Marrakech Agreement, replacing the 1948 General Agreement on Tariffs and Trade (GATT). The WTO deals with regulation of trade between participating countries. It provides a framework for negotiating and formalizing trade agreements and a dispute resolution process aimed at enforcing participants' adherence to WTO agreements, which are signed by representatives of member governments and ratified by their parliaments.

Most of the issues that the WTO focuses on derive from previous trade negotiations, especially from the Uruguay Round (1986–1994). For WTO participants, the resulting increase in national income is expected to result from more efficient use of domestic resources (e.g. movement of goods) when domestic distortions such as trade barriers are reduced or removed, and increased access to markets of trading partners.

The organization is attempting to complete negotiations on the Doha Development Round, which was launched in 2001 with an explicit focus on addressing the needs of developing countries. According to a European Union statement, "The 2008 Ministerial meeting broke down over a disagreement between exporters of agricultural bulk commodities and countries with large numbers of subsistence farmers on the precise terms of a 'special safeguard measure' to protect farmers from surges in imports." The European Commission states, "The successful conclusion of the Doha negotiations would confirm the central role of multilateral liberalization and rule-making. It would confirm the WTO as a powerful shield against protectionist backsliding." (As of July 2012, the future of the Doha Round remains uncertain. The work program lists 21 subjects for which the original deadline of January 2005 was missed.)

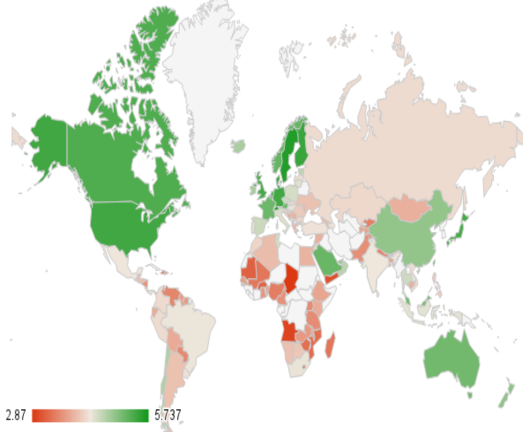
A component of WTO is an annex on air transport services which would apply to certain aspects such as repair and maintenance of aircraft, sale and marketing of air transportation, and computer reservation systems.

As trading blocs are formed within and among ICAO regions, air transport and associated modernization initiatives are expected to increase dramatically.

2.1.4.2 Infrastructure as a Competitive Tool

Inadequate and unreliable infrastructure (e.g., air, sea, and land transportation; power; telecommunications; water; and sanitation) cripples the ability of countries to engage in international trade, even of traditional export commodities. In fact, the fight for new export markets is highly dependent upon infrastructure. Figure 2-8 shows which countries and regions are the most competitive based on the *Global Competitiveness Report*.

Figure 2-8
Global Competitiveness Index



Source: World Economic Forum

Impact of ATI on Economic Development

The nature and channels of infrastructure's impact on economic development can be characterized by:

- **Economic growth through reduced cost of production:** In an aggregate sense, the character and availability of infrastructure influences the marginal productivity of private capital. This can be measured through reduced production costs. Infrastructure affects profitability, levels of output, income, and employment, particularly for small enterprises. It has a continuing impact on the costs and service quality in international trade, which determines competitiveness in import/export markets. Finally, it has an impact on domestic transaction costs and access to market information, thus permitting the economy to enjoy efficiency gains from policies of market liberalization.

- **Economic growth through structural impacts upon demand and supply:** Infrastructure contributes to diversification of economies. For example, advanced telecommunications provides access to application of technology in many sectors. It is also key to the economy's ability to adjust the structure of demand and production in response to changing price signals.

- **Economic growth through increase in productivity of other factors:** Infrastructure is essential to create the productivity gains from urbanization. When infrastructure problems result in congestion and negative net impacts on the environment, the growth potential of an economy arising from urbanization is sacrificed. Improved infrastructure reduces worker time spent on non-productive activities and improved health. Finally, efficient production and financing of infrastructure services can reduce wasteful consumption of land, water, or fuel, and contribute to protection of natural resources.

- **Raising the quality of life:** Infrastructure creates amenities in the physical environment, such as cleaner water and air, and provides spatial order, zoning, etc. It also provides outputs which are valued in their own right such as easy transportation and communication services.

Financing has important implications for economic stability. In poor and wealthy countries alike, infrastructure investment can generate employment and consumer demand in countercyclical conditions. If infrastructure projects are well chosen, the benefits can be long-term.

The positive impact of the above factors upon the air transport community is wide-ranging and usually highly visible. The community includes the usual stakeholders in the industry: airlines, airports, civil agencies and the traveling public. The positive impacts of investment in airports, aircraft, and related goods or assets will derive primarily from the services generated. Four conditions are necessary to realize the greatest impact of ATI and related CNS/ATM modernization upon any nation's economic health and are magnified when applied to developing economies:

The national economic climate should be conducive to an efficient allocation of resources, thereby reducing the potential for investment in infrastructure to take resources away from more productive investment. For example, why invest in modern ATC equipment when only certain aircraft can enter a certain region of a country on a charter basis.

ATI projects can only create synergies with other infrastructure given a sufficient complement of other necessary resources. For example, airport modernization cannot take place until roadways have the capacity to carry increased traffic flows.

Infrastructure that balances both production and consumption of goods and services will have the longest-term impact. For example, in CNS/ATM modernization, developing the navigation augmentation systems (such as the FAA Wide Area Augmentation System, or WAAS, program) in accordance with national policies for spatial referencing in non-aviation markets will benefit consumers. (Garmin automobile navigators give consumers a set-up choice between WAAS or EGNOS.)

Infrastructure will be better utilized when maintained and will impact the environment less if user charges are visibly levied and sequestered for construction and maintenance purposes.

Choosing between infrastructure investments using cost- benefit analysis or economic rates of return provides some interesting insights. Infrastructure has been a major focus of World Bank lending since its founding, and currently accounts for some 40 percent of its loans.

Key Issues to Expand ATI Investment

Possible solutions to encourage investment and expand ATI can generally be dealt with in four categories.

Technological: No technological barrier exists to resolve any of the airspace problems — that is, the necessary technologies are available virtually off-the-shelf. For example, air traffic management can be easily accommodated over the oceanic regions by ICAO's Global Blocks initiative. The program will utilize GPS and other satellite navigation systems, as well as satellite communications, for surveillance and reporting purposes. ADS and automated en route ATC enhancements could greatly expand airway capacities.

Financial: The tens of billions of dollars needed for all categories of ATI, including CNS/ATM systems, avionics, and the like, will compete largely in capital markets with funds required for other industrial sectors. If government is a financial contributor to these modernizations, lengthy delays can be expected, as most governments are cash-strapped. (See per capita debt figures of each of the countries or regions in the Appendix of this study.) The most likely scenario will be the corporatization or privatization of much of the CNS/ATM infrastructure. Government-backed bond funding can occur in a cycle tied to needs, as opposed to political agendas.

Environmental: Environmental concerns pose the greatest challenge in infrastructure development and include noise, emissions, waste, and toxic materials from airport operations.

Institutional: The institutional dimension involves international, multinational, national and labor elements. International bodies led by ICAO and regional organizations, such as Europe's ECAC, will play a continuing role in standards setting, international treaty resolutions, etc. At the airport level, it is often the city or state/province/county that first eyes an airport as a source of tax revenue. The needs of the traveling public are second to those of the tax collector, who is often oblivious to the importance of infrastructure maintenance and ATC systems upgrades.

The challenges of air traffic growth and ATC modernization can be driven by many other external factors. Over the past five years, the world has seen enormous political changes, and part of the fall-out of those changes has been the creation of new states that view participation in growing worldwide air commerce as essential to their economic survival and independence.

2.1.4.3 Liberalization and Deregulation of Air Transport Services

Air transport services continue their trend toward liberalization in and between growing numbers of countries and a substantial number of new or amended bilateral air services agreements continue to be reported to ICAO. The essential steps include further opening of borders - possibly through a simplified visa system liberalizing air transport within each region and internationally, and investing in infrastructure.

2.1.4.4 De-Institutionalization of Civil Aviation Agencies

Most civil aviation agencies are of an "extended enterprise" nature with important stakeholders who will need to understand and have a continuing role in the many steps of the modernization process. Often the pathway chosen for modernization is through the corporatization or privatization of the civil aviation authority, in which case existing laws or regulations in place to protect the many stakeholders may dramatically alter the pace of change. Below is a discussion of some of these attributes and constraints:

- **Extended enterprise defined:** A country's federal legislative entity, local governments, and airlines are all controlling stakeholders with real veto powers, and will often need to understand and have a defining role in every step of the change process. This extended enterprise incorporates the concept of shared power, fragmented decision-making, and all-inclusive strategic planning.

- **Safety mission:** Restructuring actions must not compromise safety. Safety should be enhanced through a restructuring program that emphasizes streamlining, simplification, efficiency, and improved investment in safety from funds generated by lowering costs elsewhere.

- **Culture:** The civil aviation agency of a country is a representative government agency with the resident bureaucratic resistance to change, due in part to regulations governing its affairs. With the FAA, for example, federal acquisition regulations and federal employment governance pose constraints not easily overcome by the conventional restructuring methodology which an independent organization would select. Some changes (i.e., corporatization) will possibly require legislative action.

- **Measures of performance:** This is an organizational paradigm. Most civil aviation agencies are not business-like entities with the systems and measures of performance needed to manage themselves efficiently. For example, the lack of visible, activity-based costing or financial systems will pose a hindrance to any reorganization as it will be challenging to put a stake in the ground (i.e., where we are versus where we would like to be) when a performance yardstick is not yet available.

- **Promoting international competitiveness:** In more developed countries, the rationalization of a nation's domestic or indigenous CNS/ATM technologies ensure that the civil aviation agency is doing its part in helping industry to compete in the modernization of the world's ATC systems. Intensive civil agency leadership and cooperation are needed to define and develop standard, interoperable ATC systems, which are often used to influence international standards.

2.1.4.5 Privatization and Commercialization

Functional failure is the classic economic rationale for government intervention in markets. Market failure is the inability of private markets to provide certain goods and services even though that provision is economically justified. Government market intervention may be:

- **Direct:** the legislation and administrative regulation of prices, quality of service, entry or exit.

- **Indirect:** through development of anti-trust regulation intended to control firms in the unfettered exercise of their market power.

In both developed and developing countries, the markets for transport services have been a traditional subject of public control, going well beyond the regulations that have health and safety as their motives. Rate regulations in the railways, entry restrictions in the trucking business, and control of air routes are examples of the means available through regulation to accomplish more than just supply of essential services. The true economic test of whether regulations are appropriate may be to examine whether the regulation improves the allocation of resources. That test is the starting point of the decade-old global trend toward regulatory reform, primarily through privatization or commercialization of government-run transportation facilities.

Regulation is the alternative to privatization, and while it tends to protect firms from competition, government monopolies are neither disciplined by the market nor by the regulator. Privatization and deregulation are alternative ways to restore competitive private markets to industries that governments have traditionally controlled.

In the global air transport industry, privatization is occurring at all levels and is encompassing airports, airlines, civil aviation organizations, and even some ATC equipment suppliers.

The significance of privatization or corporatization arises from the fact that many stakeholders are beneficiaries of efficient and safe air transport, and the propensity to invest in modernized ATC systems and procedures increases once bureaucratic bottlenecks are lessened and available funds increase.

Furthermore, because so many governments today are financially constrained, they have political as well as financial reasons to distance themselves from air transport policies. Privatization is often the only route to modernization. Below are discussed the trends in each of these categories.

Airports

Today there is a trend for governments to establish autonomous authorities for airport operations. According to investment and merchant bankers, airports are very attractive investments because of the high quality cash flow providing superior dividend yield and capital growth through property-related development.

Industry stakeholders such as air carriers and other interest groups claim that commercial airports have been “bought and paid for” by the airlines, their passengers, and other users, not by general tax revenues. Certain controversy exists in the debate on airport operations and control. The argument is made that privatization means passengers will have to pay a second time for airport facilities. According to some, all analysis of privatization points toward higher costs for the customer and irreparable damage to the very assets privatization is intended to enhance. These groups see no public benefits, such as capacity enhancement or increased competition, inherent in the privatization of airports.

The airlines and organizations such as IATA generally oppose the total privatization or outright sale of airports, believing that those local governments which subsidize airport operations — in an effort to attract air service and retain jobs — will cease subsidization totally. This, in turn, would result in higher operating costs for airlines and, consequently, higher airfares for consumers. Experiences in many countries, however, negate this theory.

While airport privatization is a matter of increasing demand for countries, it is difficult to find common approaches as needs are not entirely common either. For example, the importance of airport management and privatization on ATC modernization varies drastically among countries and regions. An essential component to ATC modernization in a small country may be the need to “bundle” financing for airport modernization with ATC equipment upgrades and even aircraft fleet transformation.

In larger, developed countries such as Germany or Canada, it is not so easy to connect airport modernization directly with ATM requirements linking airports. Countries where privatization programs at the airport level are underway are generally the most likely to consider upgrading ATI and acquiring the necessary funding.

Airlines

Airline privatization impacts the CNS/ATM modernization process in several ways. Countries whose national airlines must compete for international tourists need to offer competitive fares, safe and efficient flights, and reliable on-time service. This is especially the case with countries whose national incomes are supplemented by tourism, such as the Caribbean or the islands of the Pacific. Profit-making airlines or those whose role in national economies is strategic in nature are much more vocal and active advocates of the CNS/ATM modernization process. It is recognized that inefficient airspace infrastructure is usually a prime culprit in operating losses or in national competitive disadvantage due to safety or efficiency concerns of Western travelers and tourists.

The trend toward partial or full privatization of the world's airlines continues. Governments seek an acceptable balance between perceived needs to attract foreign investment in these carriers and the desire to ensure that management and control remain with their nationals.

Air Traffic Control and Civil Aviation Agencies

The corporatization and/or privatization of national air traffic management services is one of the most significant trends to impact ATC modernization this decade. A recent global recession and difficult economic times impact the flying public, forcing all nations, particularly those who are debt-strapped, to re-examine the way operations and CNS/ATM modernization are managed and financed. While corporatization is not a political altruism, often governments are reluctant to continue supporting air traffic management services from their taxpayers' pockets. Thus, a shift to self-sufficiency can be politically expedient.

Privatization generally means private ownership within a capitalist market economy or socialist market economy, an element of direct competition and profit-driven decision-making. In terms of privatization of air traffic control systems organizations, the major, or often sole, shareholder is the state. This is largely because air traffic control is partly a police and military matter and therefore is subject to state control. Therefore, in strict terms of national economic as well as airspace sovereignty, air traffic control cannot be privatized without significant penalty. What is occurring across the world is more like a "denationalization" of air traffic control, the process of liberating air traffic control from the rigid structures and constraints of the state.

In general, arguments for privatizing air traffic services are similar among different countries. Key motivation factors favoring privatization include:

- Lack of state funds for modernization.
- Weakness in the current ATC system brought about through institutional misalignments, extensive bureaucracy, and cost inefficiencies.
- Overly restrictive and debilitating personnel recruiting policies.
- Strict procurement policies.

Corporatizing and privatizing air traffic services will increase the flexibility to make air traffic improvements in a realistic timeframe and in a more business-like manner. The increased efficiencies derived from airspace capacity improvements are anticipated to translate into significant taxpayer savings. Arguments exist that safety enhancements will follow in a system more capable of absorbing the dramatic advances in ATC technologies so long as implementation of needed modernization occurs in a seamless improvement program environment.

Independence and financial autonomy have their price. Prior to the privatization of an ATC organization, capital outlay for investments and costs for reducing risks are generally borne by the state. When an ATC organization is privatized, it must be prepared for higher initial expenditures and must therefore build appropriate reserves. Generosities once shared by the state in user-cost calculations will no longer apply following privatization. The privatized ATC organization will experience additional cost increases and will be required to bill its users in full for services.

As a bureaucratic organization the fundamental tenet of ATC has been, and will remain, safety. Yet as an independent organization, ATC must redirect its approach by becoming more cost-conscious and business-like. In any country that privatizes its air traffic management services, the government will likely remain in charge of the regulatory safety function, while the management of the air traffic services operations is taken over by a government-owned or board-overseen corporation. Making ATC organizations financially independent of their respective governments may sometimes be more costly. However, with the additional accountability for safety through airline oversight and management participation, general savings can be expected to accompany improved operational safety.

When considering the financial losses that national economies bear due to outdated air traffic control equipment, it is important for ATC organizations to be able to adapt quickly to changing air traffic demands. Users could be disappointed with the prospect of paying higher air traffic costs, yet they are willing to pay higher costs for better and more efficient service. Therefore, increased costs become viable investments which, in turn, benefit users. From this standpoint, privatization of ATC services clearly profits all users.

Large airlines which pay the bulk of user fees tend to favor privatizing. However, general aviation groups fear that an ATC corporation responsible for its own finances could trigger higher costs for its services. In doing so, it would be alienating an important stakeholder in the corporatization initiative — the general aviation community.

Impact of Privatization on CNS/ATM Modernization Programs

In coming years, the impact of privatization trends upon CNS/ATM modernization programs will be profound. Most important is the way civil aviation organizations, airports, and airlines will buy new systems for air traffic control. Decisions will likely be made on the basis of best value, lowest risk, and performance. Gone will be the days of purchasing from vendors that may not offer the best or most cost-effective (value-driven) technological solution.

Additionally, the customer will be different. In many instances today, modernization will occur through an international open tender. Development banks such as the European Bank for Reconstruction and Development (EBRD) seed modernization through full and open international competition.

Suppliers of CNS/ATM equipment who recognize this trend will be well served to sharpen their skills for the highly competitive open bidding scenarios of future modernizations.

2.1.4.6 CNS/ATM and Harmonization

Harmonization is the attainment of a comparable level of operational performance by utilization of compatible standards, specifications, and ATC operational procedures. Harmonization also extends to the regulatory and certification process.

Most countries have accepted the imperative of developing and implementing the CNS/ATM system of the 21st century. Making this a compelling task, however, is the rapid evolution of new classes of technologies in communications, navigation, surveillance, air traffic management, weather, safety, and security. The potential regional or country-specific differences in systems architectures and acquisition approaches pose obstacles to achieving harmonization.

Harmonization is sometimes a painful process because of a parochial reluctance that resists the harmonizing efforts. The major reasons for this are the additional workload and the insular quest of ownership. However, the benefits of harmonization of standards and the resulting worldwide market for suppliers are immense. The price of not achieving harmonization will, of consequence, be significant.

2.1.4.7 CNS/ATM and Globalization

Globalization represents movements of companies into multiple national and international markets, directly or indirectly, through alliances, franchises, or direct investment. This trend has been present in the air transport industry because air transport is needed to support global trade. International air carriers, airplane manufacturers, and ATC equipment suppliers have for years operated globally and understand that international market share is the key to success. Advancing technological drivers are forcing the hand of managers of these enterprises. It is becoming increasingly difficult to separate technology issues from policy and market forces.

CNS/ATM technologies, especially in the realms of satellite CNS and automation, are evolving rapidly and present significant challenges for the clients of ATC equipment suppliers, the civil aviation agencies. Because the acquisition of major ATM systems takes from five to ten or more years, automation system designs need to consider how evolving capabilities (such as the rapid and seemingly endless improvements in communications and satellite navigation) can be exploited along the way.

Improving technological performance in a world of constant change is by no means a simple task. Establishing a satellite-based ATM environment will inevitably encompass changes in business practices and organizations with responsibility for air traffic management and related ATC equipment. A large percentage of personnel in CNS/ATM are the air traffic controllers, whose jobs are defined by automation. Therefore, each upgrade necessitates due consideration of technologies in business process definition, design, and reengineering. The challenge of organizational change comes from the modification to processes and procedures established through regulatory and policy initiatives. Technology alone will not change the business process nor the organizations involved with the specific practices.

The continuing march toward globalization of the air transport industry itself requires a careful consideration of who the customer is, internally and externally. In many parts of the world, ATC organizations are referred to as services, as opposed to authorities, with the main purpose of the organization to provide a necessary function in ATC. In turn, it is important that the air traffic services (ATS) organization be properly oriented toward the customer, that is, the person and/or business that is the immediate recipient of the service. One of the challenges of globalization is the fact that from region to region, and from nation to nation, this customer varies.

2.1.4.8 Multinational Facilities and Services

As satellite-based CNS begins to take hold throughout all ICAO regions of the world, a fundamental institutional issue remains to be dealt with regarding the ownership and control of these assets. To assist states and regional bodies, ICAO has developed guidelines on organizational, financial, and managerial aspects of multinational facilities and services. Particular effort is now being devoted to expanding such guidance to specifically facilitate the implementation of various components of CNS/ATM systems, and to test the boundaries of joint ownership — a challenge for civil aviation agencies not used to being minority owners of critical hardware and services, thereby raising questions of sovereignty.

For example, Global Navigation Satellite System (GNSS)capabilities and applications continue to grow rapidly and are expected to have substantial usage by civil air transport, marine, land, and survey/mapping/geographic information systems (GIS) users. Political and economic factors could well lead to a shift to civilian control and possible modifications to aspects of the system. Uncertainty created by factors such as long-term ownership and control of GNSS is having a profound impact upon the ultimate adoption of global ATM equipment and standards. A satellite navigation system whose control rests firmly in the hands of the governments or militaries will slow international adoption and feed the search (and duplicative waste of resources) for alternative satellite assets.

Internationally Shared Assets — Government or Civil Aviation Owned

Today terrestrial and satellite CNS remains the area of the most intense activity in joint ownership. Many countries are pooling capital asset resources in modernization drives to improve the performance of air navigation regions. Inter-regional programs are also underway. Internationally shared assets in communications, navigation, and surveillance will become the hallmark of 21st century air traffic management systems.

The European ICAO region is an area of extremes. In certain areas, state-of-the-art ATC equipment, facilities, and services are available, while in others outdated infrastructure exists. More often than not, European region ATC facilities compete with incompatible air navigation systems and methodologies.

European airlines and airline trade associations, such as IATA and the Association of European Airlines (AEA), are pushing European governments to unite and implement a single European system. Associations recommend that the ATM system be formed as a distinct legal entity owned by participating nations, yet operated and managed according to business rules rather than bureaucratic government rules and regulations. The new system should be managed by a single authority, enjoy fully compatible equipment, and operate from a common set of standards, practices, and procedures. A single European ATM system would require the participation of nearly 25 nations in addition to their individual civil aviation authorities and multinational organizations. Cooperation would also be required by various military ATC systems and organizations such as the European Union, the JAA, and EUROCONTROL, all of which have distinct member nations. The effort to establish a single European ATM should begin with a wide-ranging R&D effort to develop an advanced ATM system to provide the ATC capacity to meet increased air carrier demands.

Implementing a satellite-based CNS will likely lead to widespread use of the space-based assets throughout the spectrum of transportation systems. Additionally, funding and budgeting issues will become complex in an international context. ICAO may be called upon to play an increasing role in the funding or operation of these assets.

Internationally Shared Assets - Airline Industry Owned

Airlines were aware of the cost-effectiveness of jointly managed air traffic systems decades ago. In the 1930s, US airlines began to share weather services and data. Voice communications were next, with the introduction of the Aeronautical Radio Service, which is now a global voice and data network whose assets are owned by the airline industry. These initiatives are now viewed more from a business value perspective.

It is highly unlikely that continued expansion in joint airline ownership of airway facilities will continue. In addition to national or agency concerns, debate also revolves around the potential or perceived conflict of price fixing in commonly-owned airline ticket reservation systems.

2.1.4.9 CNS/ATM and Information Technologies

In today's business environment, change is constant, and successful air transport organizations have developed evolutionary methods for evaluating and improving how they go about their business. This is not yet the case in the government side of the air transport sector.

Leaders of government are, however, placing priority on finding new ways to work through the changes ahead. In the civil aviation community, long dominated by national bureaucracies, many of the traditional organizational strategies dealing with change are obsolete or are becoming so. In an environment of constant change, new perspectives and attitudes are essential if an organization is to do better than merely survive. Bureaucracies are being compelled to become more "business-like" because of the financial imperatives of modernization and the importance of international trade. These organizations need a better understanding of the impact they have upon national competitiveness and of the positive influence modern infrastructure development brings to their national trade.

The more forward-thinking civil aviation leadership is not looking for small, incremental changes, but for advice on larger issues that cut to the core of their missions and how they use their infrastructure to aid national competition in the world marketplace. This paradigm is sought to fundamentally rethink an organization's business, identify core competencies, and leverage the organization's resources. Central to this is the information technology component: how to integrate IT planning with organizational strategy, and ultimately to measure the impact of IT on operational performance.

Traditionally, IT was applied to automate manual tasks with minimal thought given to whether the underlying processes were aligned with the organization's current business plan. Measures used to evaluate the merits of IT (in the case of this study, CNS/ATM automation), must include metrics that clearly demonstrate a return on investment to the organization and its customers.

Most ANSPs, both public and private sector, express frustration at being unable to close the gap between their investment in automation technologies and the contribution that this investment is expected to make in productivity, efficiency, and profitability. Measuring value and linking investment to automation is complex and disquieting. However, modernized CNS/ATM and advanced automation of airways will be key to harnessing the power of change and radically improving organizational performance of civil aviation agencies globally.

Key Points:

- The continued globalization of the aviation industry is revolutionizing air traffic policies with respect to deregulation, liberalization, and harmonization policies.
- These trends are pushing the industry to focus on the flexibility offered by privatized services and the advanced skill sets of multinational capabilities.
- The ability to build adaption and change into products and services will become a key differentiator for ATI suppliers and buyers.

2.2 Institutional Drivers and Benefits of Emerging CNS/ATM Systems

Large investments by the world's airlines in new aircraft, many equipped with advanced flight management systems, have been driven by efficiency concerns and strong growth in passenger demand. Airspace use and capacity have not kept pace with this increase in demand and, as a result, air traffic services provided through modern CNS/ATM procedures and systems are lacking. This compounds the already major efficiency penalty for airlines, which cannot maximize or, in some instances, recoup their investment in these state-of-the-art aircraft.

Exacerbating the problem is the fact that governments insist upon maintaining civil aviation agency control and management of airway facilities. By doing so, national governments:

- Overstress civil aviation oversight under the guise of zero tolerance of safety violations.
- Perpetuate government oversight, especially in procurement processes and regulations.
- Apply the same employment and union structures to the "safety critical" civil aviation agency as may be enjoyed by all other national agencies, most of whom are not involved in an "extended enterprise" environment.
- Restrict timely access to needed funding for modernization, giving priority to funding needs that are politically more expedient.

This institutional problem is slowly being examined, often under the force of crisis (financial or otherwise), as identified in other sections. A review of the physical shortcomings and limitations in CNS/ATM follows, and the underlying institutional issues are identified.

2.2.1 Limitations of Present Communications, Navigation, and Surveillance, and New Concepts

Due to terrain limitations in many regions of the world, it is difficult, if not impractical, for current terrestrial CNS systems to be used. Even with greater coverage, wider implementation brings with it other severe constraints which limit effective air traffic management.

Modes of air traffic and corresponding density characteristics will dictate new CNS system evolution by mode of operation. A comprehensive assessment of the characteristics and capabilities of the present CNS system and of their implementation in various parts of the world reveal several shortcomings:

- The propagation limitations of current line-of-sight systems for CNS include wide variations in capacity, range of operation, accuracy, availability, and reliability.
- Severe limitations of voice communications, the principal media for ATC and ATM control, and the lack of reliable, high-capacity digital air-to-ground data interchange.
- The institutional difficulty of implementing present CNS systems and operating them in a consistent manner (harmonization of systems and interoperability of equipment) in large parts of the world.

Although their effects on air system capacity and efficiency vary widely, these limitations are inherent to the existing systems in place in the various ICAO regions. In fact, one or more of these factors inhibit the further development of air commerce capacity and efficiencies worldwide.

For example, over the oceans the systems currently approved for use are severely limited. Thus, air-to-ground communications can be accomplished only through HF/VHF radio and limited datalink communications, often with the need for intermediate communicators. While on-board navigation systems incorporate GPS and are available to larger aircraft, long-range navigation has been limited to pilot reports of position via HF/VHF voice or basic data transmissions. These limitations have resulted in a wasteful use of airspace (a contradiction over most ocean regions) and very large separation minima.

New CNS systems should surmount these limitations and, through improved ATC systems and procedures, allow for the expansion of ATM concepts on a global scale.

2.2.2 Limitations of Existing Air Traffic Management, and New Concepts

Around the world, the general objective of ATM is to enable aircraft operators to meet their planned times of departure and arrival, and to adhere to their preferred flight profiles optimized to their equipment and procedures. ATM assumes that minimum constraints are imposed and safety is not compromised. Air traffic management is considered to consist of three elements: airspace management (policy), traffic flow management, and air traffic control. Presently, CNS/ATM is an evolving system and methodology which, as one looks throughout the world, suffers a number of shortcomings, including:

- Insufficient number of terrestrial surveillance systems over large regions of the globe, many of which require relief from congestion.
- Air route availability constrained by terrestrial navigation aids which, due to their location or density, create bottlenecks.
- Dissimilar air traffic control procedures, requiring modification of flight profiles.
- Dissimilar separation standards, requiring modification of flight profiles.
- The uncoordinated provision of present CNS equipment, resulting in the duplication of resources and services.
- A lack of appropriate parallel route structures to relieve route congestion.
- Poor quality and incompatible communications facilities.

- International language difficulties.

The new CNS systems will make improvements in their own right, but will also form the technological basis for a step change improvement in ATM. This will permit a more flexible and efficient use of airspace, both en route and in terminal areas. This is needed to improve the accommodation of the preferred profile in all phases of flight. In particular, airspace boundaries are to be made transparent to the users.

Key Points:

- Major impediments to existing ATM include: insufficient surveillance, terrestrial navigation constraints, congestion from rigid route structures, disparate ATC procedures, and uncoordinated communications.

- New technologies and systems must address these concerns to be valuable to ATM providers.

2.2.2.1 Next Generation Air Transportation System (NextGen)

The Next Generation Air Transportation System (NextGen) is the name given to a new national airspace system (NAS) due for implementation across the US in stages between 2012 and 2025. NextGen proposes to transform America's air traffic control system from an aging, ground-based system to a satellite-based system. GPS technology will be used to shorten routes, save time and fuel, reduce traffic delays, increase capacity, and permit controllers to monitor and manage aircraft with greater safety margins. Planes will be able to fly closer together, take more direct routes, and avoid delays caused by airport "stacking" as planes wait for an open runway. The FAA will undertake a wide-ranging transformation of the entire US air transportation system with the aim of reducing gridlock, both in the sky and at the airports.

Once implemented, NextGen will allow pilots and dispatchers to select their own direct flight path rather than using a grid-like highway system. By 2020, aircraft are expected to be equipped to inform pilots of their exact location in relation to other aircraft, thereby enabling planes to fly more closely together with the same level of safety. NextGen's increased scope, volume, and distribution of information is intended to help planes land faster, navigate through weather better, and enjoy reduced taxi times so flights and airports themselves can run more efficiently (Figure 2-9 p. 36).

NextGen Elements

NextGen consists of many systems in a highly interrelated (operational and information architecture) system-of-systems:

Automatic Dependent Surveillance-Broadcast (ADS-B). ADS-B will use GPS satellite signals to provide air traffic controllers and pilots with much more accurate information that will help keep aircraft safely separated in the sky and on runways. Aircraft transponders receive GPS signals and use them to determine the aircraft's precise position in the sky. These and other data are then broadcast to other aircraft and air traffic control. Once fully established, both pilots and air traffic controllers will, for the first time, see the same real-time display of air traffic, substantially improving safety. The FAA will mandate the avionics necessary for implementing ADS-B.

System Wide Information Management (SWIM). SWIM will provide a single infrastructure and information management system to deliver data to many users and applications. By reducing the number and types of interfaces and systems, SWIM will reduce data redundancy and better facilitate multi-user information sharing. SWIM will also enable new modes of decision-making as information is more easily accessed.

Next Generation Data Communications. Current communications between aircrew and air traffic control, and between air traffic controllers, are largely realized through voice communications. Initially, the introduction of data communications will provide an additional means of two-way communication for air traffic control clearances, instructions, advisories, flight crew requests, and reports. With the majority of aircraft datalink equipped, the exchange of routine controller-pilot messages and clearances via datalink will enable controllers to handle more traffic. This will improve air traffic controller productivity, enhancing capacity and safety.

Next Generation Network Enabled Weather (NNEW). Every year, 70 percent of NAS delays are attributed to weather. The goal of NNEW is to cut weather-related delays at least in half. Tens of thousands of global weather observations and sensor reports from ground, airborne and space-based sources will fuse into a single national weather information system, updated in real time. NNEW will provide a common weather picture across the national airspace system, and enable better air transportation decision making.

NAS Voice Switch (NVS). There are currently seventeen different voice switching systems in the NAS, some in use for more than twenty years. NVS will replace these systems with a single air-to-ground and ground-to-ground voice communications system.

Implementation

The FAA is pursuing a NextGen implementation plan and has established a NextGen Advisory Committee to aid in that implementation. In 2009, the advisory committee began collaboration with the Radio Technical Commission for Aeronautics (RTCA) Task Force, a joint government and industry group, to participate in the effort. Besides the FAA, the RTCA Task Force membership includes the Air Line Pilots Association, the Air Transport Association of America, Aircraft Owners and Pilots Association, The Boeing Company, the US Department of Defense, Garmin International, Honeywell International, Rockwell International, Stanford University, Lockheed Martin, MIT Lincoln Laboratory, Harris Corporation, NASA, National Business Aviation Association, and Raytheon.

Benefits

The FAA estimates that increasing congestion in the air transportation system of the US, if unaddressed, would cost the American economy $22 billion annually in lost economic activity by 2022. It also estimates that by 2018, NextGen will reduce aviation fuel consumption by 1.4 billion gallons, reduce emissions by 14 million tons, and save $23 billion in costs. Each mile in the air costs an airline about $0.10-$0.15 per seat in operating expenses like flight crew and fuel. Flying directly from one airport to the next and reducing congestion around airports can reduce the time and miles spent in the air for the same trip.

According to the FAA, the implementation of a surface management initiative in Boston saved 5,100 gallons of aviation fuel and reduced carbon dioxide emissions by 50 tons during a period of heavy congestion. A shared surface surveillance system combined with aircraft metering techniques reduced taxi-out time by 7,000 hours a year at New York's JFK airport and 5,000 hours a year in Memphis. Helicopters flying over the Gulf of Mexico are also using NextGen technology to manage poor weather conditions and in Colorado to navigate through dangerous mountain terrain.

There has also been a demonstration in Memphis with Delta Airlines and FedEx. The National Air Traffic Controllers Association (NATCA) conducted a demonstration at Dallas/Fort Worth International Airport (DFW) of a new surveillance display called the Tower Flight Data Manager (TFDM) system that would present surveillance, flight data, weather, airport configuration, and other information critical to controllers. Specialized optimized profile descents, also known as initial tailored arrivals, have moved from the demonstration phase to operational use at airports in San Francisco, Los Angeles and Miami.

In June 2010, European and American authorities reached a preliminary agreement on interoperability between their future air traffic management systems, SESAR and NextGen. In March 2011, the FAA released the latest version of its implementation plan. As of July 2011, JetBlue and Southwest Airlines had installed onboard equipment, partly with federal funds.

Challenges

Critics state that the FAA faces considerable challenges in implementing a satellite-based NextGen ATC system, ranging from delays in approving new procedures and technology to skepticism among airlines regarding investment in new equipment.

Airline skepticism: Airlines must invest in equipage in order for NextGen to work. However, airlines' greatest fear is not that benefits will not materialize, but rather that FAA may not produce promised NextGen capabilities on time. Airlines want performance guarantees in order to begin equipping their fleets with expensive NextGen avionics.

Costs: Ongoing problems continue to threaten NextGen's costs and timeline. A report released in October 2011 by the Government Accounting Office (GAO) found the FAA has made some progress in implementation, but delays threaten to impact costs and benefits. Specifically, some acquisitions have been delayed, which has impacted the timelines of other dependent systems. The report also indicates that some key acquisitions may soon encounter delays, which can increase overall acquisition costs as well as costs to maintain current systems. For example, delays in implementing the En route Automation Modernization (ERAM) program, critical to NextGen, is projected to increase costs by $330 million, as well as an estimated $7 to $10 million per month in additional costs to continue maintaining the system that ERAM was meant to replace.

NextGen program interdependencies: Due to the integrated nature of NextGen, many of its component systems are mutually dependent on one or more other systems. For instance, the delivery of ADS-B depends on ERAM because ADS-B requires the use of some ERAM functions. Additionally, ERAM is instrumental to the on-time implementation of two other crucial NextGen acquisitions—data communications and SWIM. The FAA pushed the data communications program's start date from September 2011 to February 2012 and delayed the SWIM segment 2 start date from 2010 to December 2012 in part due to ERAM's delay. The long-term result of this decision is not yet known, but it could delay certain SWIM capabilities as well as hinder the progress of other capabilities that depend, in turn, on the system integration that SWIM is intended to provide. Consequently, the mid-term (through 2018) and long-term (beyond 2018) implementation of NextGen will be affected by how well FAA manages program interdependencies.

Potential budget reductions: The delays in program implementation and budget constraints have also affected FAA capital budget planning. Congress has proposed reducing the FAA's capital budget by a total $2.8 billion (20 percent) for fiscal years 2012 through 2016 largely due to government budget constraints. Most of this proposed reduction will fall upon NextGen and NextGen-related spending, as reflected in FAA's revised five-year Capital Investment Plan for fiscal years 2012 through 2016. The FAA will have to balance its priorities to ensure that NextGen implementation stays on course while also sustaining the current infrastructure needed to prevent failures and maintain the reliability and efficiency of current operations.

Effect of delays on the FAA's ability to collaborate with Europe: Delays to NextGen programs and potential reductions in the budget for NextGen activities could delay the schedule for harmonization with Europe's air traffic management modernization efforts and the realization of these benefits.

Environment

Another issue in implementing NextGen is expediting environmental reviews and developing strategies to address its environmental impacts. A previous GAO report on environmental impacts at airports indicated that due to the changes in aircraft flight paths as a result of NextGen, some communities that were previously unaffected or minimally affected by aircraft noise would be exposed to increased noise levels. These levels could trigger the need for environmental reviews, as well as raise community concerns. The report found that addressing environmental impacts can delay the implementation of operational changes and indicated that a systematic approach to addressing these impacts and the resulting community concerns may help reduce such delays. It is worth noting that the FAA is working on developing environmental review processes that affect NextGen activities.

2.2.2.2 SESAR Joint Undertaking.

The SESAR Joint Undertaking (JU) is the European public-private partnership managing the development phase of the Single European Sky ATM Research (SESAR) program that will give Europe a high-performance ATM infrastructure resulting in the safe and environmentally friendly development of air transport. The objectives of this program are, by 2020, to save per flight operation:

- 8 to 14 minutes.
- 300 to 500 kg of fuel.
- 948 to 1575 kg of CO2.

SESAR Phases

SESAR's goal is to develop the new generation air traffic management system capable of ensuring the safety and fluidity of air transport worldwide over the next 30 years.

The first phase (the definition phase) delivered the ATM master plan that defines the content, the development, and deployment plans of the next generation of ATM systems (2009).

The development phase (2008-2013) will produce the required new generation of technological systems, components, and operational procedures as defined in the SESAR ATM master plan and work program.

The deployment phase (2014-2020) will see the large-scale production and implementation of the new air traffic management infrastructure, composed of fully harmonized and interoperable components guaranteeing high performance air transport activities in Europe.

The total estimated cost of SESAR's development phase is €2.1 billion ($2.57 billion), to be shared equally among the European Community, EUROCONTROL, and the industry, each receiving €700 million ($858 million). (Figure 2-10)

EC Decision

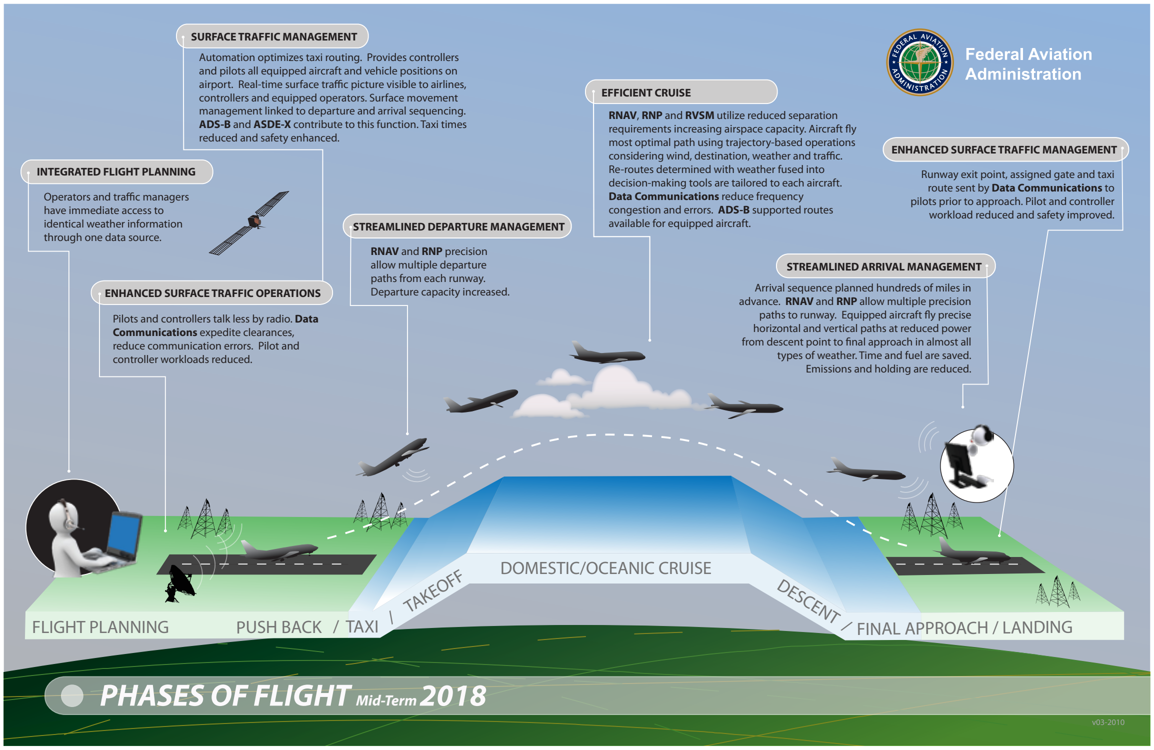
In March 2009, the Council of the European Union officially endorsed SESAR's European air traffic management master plan. The ATM master plan provides the road-map for the development and deployment phases of the SESAR program which constitutes the technological pillar of the Single European Sky policy. SESAR aims at developing the new generation air traffic management system capable of ensuring safety and efficiency of air transport throughout Europe over the next 30 years.

SESAR Membership and Funding

The SESAR definition phase was co-funded by the European Union and EUROCONTROL. It was carried out by the SESAR consortium established through a contractual agreement joining forces and expertise from all relevant ATM stakeholders. The SESAR consortium represented a unique initiative, bringing together European expertise in the field of ATM.

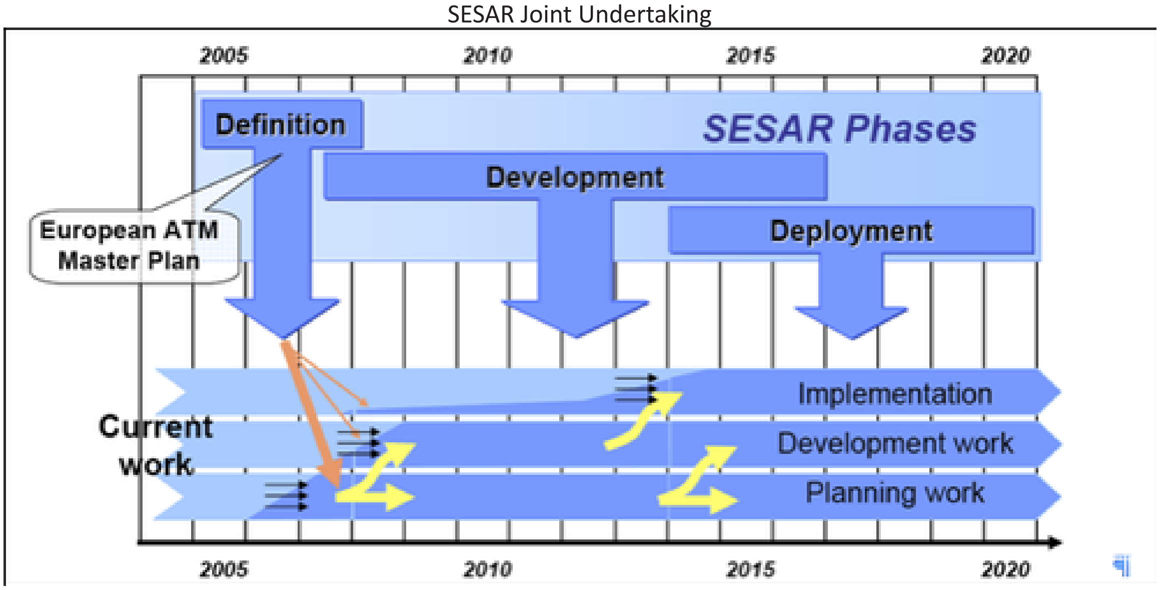
The SESAR Joint Undertaking was created under European Union law in February 2007, with EUROCONTROL and the European Commission as founding members. In addition, 15 organizations have signed a membership agreement with the SESAR JU. The program can profit from the expertise of airport operators, ANSPs, the ground and aerospace manufacturing industry, aircraft manufacturers, and airborne equipment manufacturers. With the endorsement of 13 associate partners in July 2010, the SESAR JU included additional companies with very different profiles and expertise from around the world in the SESAR work program (Figure 2-11).

Figure 2-9
NextGen



Source: FAA

Figure 2-10
SESAR Joint Undertaking



Source: SESAR Joint Undertaking

Figure 2-11
SESAR JU Partners

Founding Organizations	Associates
Aena Airbus Alenia Aermacchi Deutsche Flugsicherung (DFS) Direction des services de la navigation aérienne (DSNA) Ente Nazionale per l'Assistenza al Volo (ENAV) EUROCONTROL European Commission Frequentis Honeywell Indra Sistemas NATMIG NATS Holdings NORACON SEAC SELEX Sistemi Integrati Thales Group	Avtech Belgocontrol Boeing Luchtverkeersleiding Nederland (LVNL) Lockheed Martin NATS Services NAV Portugal Moroccan Airports Authority PANSA Società Esercizi Aeroportuali (SEA) Skyguide Thales Australia Thales Raytheon Systems

Source: SESAR Joint Undertaking

Single European Sky

The Single European Sky (SES) is a European Commission initiative by which the design, management, and regulation of airspace will be coordinated throughout the European Union (ECAA area). SES is expected to benefit all airspace users by ensuring the safe and efficient utilization of airspace and the air traffic management system within and beyond the EU. Airspace management is planned to move away from the previous domination by national boundaries to the use of "functional airspace blocks," the boundaries of which will be designed to maximize airspace efficiency. Within the airspace, air traffic management, while continuing to have safety as its primary objective, will also be driven by the requirements of the airspace user and the need to provide for increasing air traffic. The aim is to use air traffic management more closely based on desired flight patterns, leading to greater safety, efficiency, and capacity.

SESAR ATM Concepts

SESAR contributions to the overall SES objectives will come as the result of a new approach to air traffic management known as the SESAR concept of operation. Key features include:

- Moving from airspace to trajectory-based operations, so that each aircraft achieves its preferred route and arrival time.
- Collaborative planning so that all parties involved in flight management from departure gate to arrival gate can plan their activities based on the performance the system will deliver.
- Dynamic airspace management through enhanced coordination between civil and military authorities.
- New technologies providing more accurate airborne navigation and optimized spacing between aircraft to maximize airspace and airport capacity. New technologies will be embedded into a harmonized and interoperable technical architecture while supporting the needs of all European regions.
- Central role for the human, widely supported by advanced tools to work safely and without undue pressure.

SESAR Performance Goals

In 2005, the Commission stated the political vision and high level goals for the SES and its technological pillar:

- Enable a three-fold increase in capacity to reduce delays, both on the ground and in the air.
- Improve the safety performance by a factor of ten.
- Enable a ten percent reduction in the effects flights have on the environment.
- Provide ATM services to airspace users at a cost of at least 50 percent less.

The definition phase of SESAR has concluded that ATM can significantly contribute to reaching these goals. SESAR is now targeting for 2020:

Figure 2-12
SESAR Key Achievements

SESAR SL	0	1	2	3	4	5
Key Achievements	Rolling out best practices	Preparing trajectory based operations	Implementing net-centric trajectory management	Achieving advanced automation on a shared trajectory environment	Extending operations with advanced separation modes	Accommodating full 4 dimension trajectory management based on user preferred routes
Key Dates	Now / 2012	2009 / 2013	2013 / 2019	2017 / 2020	2020/2025	From 2025
Examples of Operational Improvements	• Continuous descent approach • Flexible air traffic control sectors • Continuous climb departure • Initial datalink • Automatic flight Conformance monitoring • Basic departure management • Arrival management • Ground based safety nets • Runway occupancy time optimization techniques	• Interactive rolling network operations plan • Manual user driven prioritization process • Arrival/departure management integration • Airborne traffic awareness in flight and on ground • Airborne and on ground traffic separation • Improved low visibility procedure	• Full set of complexity management tools • Airborne spacing, sequencing and merging • 2 dimension precision trajectory clearances on pre-defined routes • Automatic surface movement planning and routing • Separation adjustment based on wake vortex detection	• Dynamic terminal areas and flexible military areas • Dynamic air traffic flow management using reference business trajectory • Dynamic reference business trajectory revision using data-link • 2 dimension precision trajectory clearances on user preferred routes • 3 dimension precision trajectory clearances on pre-defined routes • Full set of advanced controllers tools • Automatic airborne separation	• Dynamic mobile areas • Free routing outside terminal areas • 3 dimension precision • Trajectory clearances on user preferred routes • Delegation of the separation 1 to 1 aircraft for crossing/passing maneuvers • Advanced safety nets with full compatibility between ground based and airborne tools • Use of synthetic vision in low visibility conditions • Remotely controlled aerodrome	• Real time adaptation of air traffic control sectors • Aircraft spacing self adjustment based on wake vortex detection • Delegation of the separation 1 to several aircraft 4 dimension precision trajectory clearances on user preferred routes

Source: SESAR

- A 73 percent increase in capacity from 2004.

- Associated improvement in safety so that the total number of ATM-induced accidents and serious or risk-bearing incidents will not increase despite traffic growth.

- A ten percent reduction per flight in environmental impact compared to 2005.

- A 50 percent reduction in cost per flight compared to 2004.

With two major objectives in the environmental fields, the SESAR program reflects the increase of environmental pressure and its importance within the ATM community. These objectives are:

- **To achieve emission improvements.** The SESAR target for 2020 is to achieve ten percent fuel savings per flight as a result of ATM improvements alone, thereby enabling a ten percent reduction of gas emissions per flight.

- **To improve the management of noise emissions and their impacts.** To ensure that these are minimized for each flight to the greatest extent possible.

Should the development phase conclude that ATM improvements on their own cannot fulfill the above objectives, the adequate co-ordination between SESAR and Clean Sky10 would allow for the necessary trade-offs between the two initiatives, ensuring that, summing up their respective contributions, the environmental objectives would remain within reach. Any evolution in respect to the expected SESAR contribution to reducing environmental impact of air transport shall be reflected in future versions of the ATM master plan.

SESAR Master Plan Schedule

Figure 2-12 presents the SESAR ATM service levels and schedule of operational improvements (key dates).

- **Service level 0:** Consists of rolling out current best practices and deploying available technologies aimed at providing the processes and system support for efficient collaborative planning and timely decision-making across the network. The on-going initiatives support the delivery of service level 0, ensuring that the improvements can be implemented in a short timeframe, provided that the required level of stakeholder involvement is secured. Initiatives such as DMEAN, LINK 2000+, etc., are highlighted.

- **Service level 1:** Aims to achieve the required interoperability between ATM partners to enable smooth migration to trajectory-based operations, taking initial benefit of the "manual" user-driven prioritization process (UDPP). The route network will be increasingly flexible to offer more options to airspace users. More advanced procedures and systems will be introduced to increase safety and throughput of airports/sectors to the performance targets for the period. This will build upon conventional modes of separation while paving the way for new methods of control. Service level 1 improvements will be carried out in compliance with the need for environmental protection.

- **Service level 2**: Introduces the fundamental changes underpinning the SESAR concept of operations thanks to the progressive implementation of a rich, informa tion-sharing environment, with SWIM supporting the shared business trajectory. More and more user-preferred trajectories will be accommodated along with functional airspace block (FAB) implementation over Europe, enabling more direct routes in upper airspace. The UDPP will be applied defining prioritization as the result of a collaborative process involving all partners. New modes of separation will be implemented (2D-PTC), and ASAS spacing applications will be introduced in terminal areas. Advanced environmentally-friendly operations will be used in higher density terminal areas, with the introduction of 3D trajectory management and new controller tools. Surface movement operations will benefit from increased automation and improved surface navigation. Positional awareness will be improved through visual enhancement technologies.

- **Service level 3:** The use of free routing is extended, and a new model of airspace categories will be introduced to pave the way to the two target categories contemplated in the SESAR concept of operations. This is complemented by airspace organizations' measures for an extensive dynamic management of en route and terminal airspace. ATC automation will benefit from full use of a 4D shared trajectory environment, thus making possible the implementation of a full set of advanced controller tools, as well as further assistance to the controllers in support of precision trajectory operations and effective queue management. First ASAS separation applications will be introduced. Flight deck automation will be increasingly used on the airport surface.

- **Service level 4**: Contributes to the transition to the ATM target concept with full implementation of enhanced trajectory management through 3D precision clearances for user-preferred trajectories and of ASAS cooperative separation applications. For airports, remote tower operations are introduced, and specific procedures based on synthetic vision systems are defined.

- **Service level 5**: The main features will be the implementation of 4D precision trajectory clearances and the introduction of ASAS self-separation in a mixed mode environment. These changes require extensive feasibility studies and will be completed as result of innovative research and as part of the master plan maintenance process.

SWIM and SESAR

SWIM has been recognized as an essential enabler of ATM applications within SESAR, the principles of which are also applied in, and supplied by, other industries. Technologies enabling SWIM capabilities required by ATM are available. SWIM as a methodology of sharing information can apply to all ATM capability and service levels. In this context, "SWIM capability level" relates in some cases to an extension of geographical/spatial availability, although different ATM service levels may equally need more advanced and/or widespread implementation of SWIM.

SWIM is an enabler of end-user applications needed in ATM and is not in itself an ATM end-user application. The concept of SWIM will make information more commonly available and consequently allow its usage by end-user applications. This prevents the constraint of otherwise necessary full deployment of airborne and ground capabilities, thus providing benefits at an earlier stage.

SWIM creates the conditions for advanced end-user applications based on extensive information sharing and the capability of finding the most appropriate source of information. For the deployment of SWIM, an approach has been selected ensuring that benefits start to accrue at the earliest possible time: this is achieved by migrating simpler end-user applications first. The deployment of SWIM is not dependent on the deployment of ATM changes. SWIM benefits are available even in a largely legacy environment.

2.2.2.3 CARATS

Asia is currently experiencing extensive international economic and social change. Asian states are enjoying rapid economic growth, and globalization is forcing the region to explore ways of coping with increased air traffic capacity constraints. Japan is attempting to confront this challenge via its Collaborative Action for Renovation of Air Traffic Systems (CARATS) program. The stated goals of CARATS are to:

- Enhance safety
- Increase ATC capacity
- Improve user convenience
- Ensure efficient operation
- Enhance ATM service efficiency
- Respond to environmental issues
- Strengthen international cooperation

As air traffic volume has increased, the number of flow control procedures and delays have gradually risen, making it difficult to maintain service levels.

CARATS is similar in concept to NextGen and SESAR, featuring a long-term vision for introducing a range of new technologies and procedures. The plan extends to 2025 and includes major initiatives in the areas of trajectory-based operations, performance-based navigation, and multilateration. In fact, with a strong commitment to multilateration, MLAT, and extensive radar coverage, Japan is reticent to commit large amounts of resources to the otherwise popular ADS-B modernization movement.

While the full funding requirement for the program is still under analysis, it is difficult to envision a full rollout, especially with government resources focused on recovering from the devastating earthquake and tsunami of 2012.

2.2.2.4 Other Regional and National Initiatives

This section presents mainstream concepts for CNS/ATM that align with US and European initiatives.

Communications

New concepts for CNS provide for flexibility, a vital consideration when one recognizes the importance that each country attaches to maintaining sovereignty over its airspace. These provide considerable flexibility, for example:

- Each country has the choice of implementing specific system elements to meet its individual requirement for forming a complete CNS/ATM system.

- Countries with busy airspace would use more than one communications system, while smaller countries with ATC priorities could adequately accommodate their traffic requirements through VHF datalink.

Communication with aircraft over many areas of the world will (of necessity) be accomplished through direct satellite-to-aircraft links. Increased capacity for voice and data communications will be required but is easily achievable with today's technologies. A mix of satellite and terrestrial systems could accommodate the vast range of density requirements and may include provision of VHF voice and datalink, Mode S, etc.

New air-to-ground datalink digital communications will be provided by satellites for oceanic and domestic en route airspace and by Mode S secondary surveillance for high density terminal areas. Voice communications via satellite will be provided in all areas of airspace, eventually to include polar regions. VHF radio communications would remain in use in domestic en route and terminal areas.

Navigation

In the near future, navigation will be provided by some form of GNSS, comprising GPS, Galileo, or GLONASS, for use in oceanic, domestic en route, and terminal area airspace, with much higher standards in accuracy and integrity than current terrestrial navigation capabilities. The WAAS/EGNOS concepts implemented in the US and Europe will form the basis for improved integrity and continuity.

There will not be a single international standard for aircraft navigation. Rather, a required navigation performance (RNP) classification system will be introduced which will allow users (aircraft owners) and providers (civil aviation and air traffic controllers) some degree of flexibility in procuring various navigation systems with different levels of capability.

The concept of RNP is that for each airspace area (en route, terminal, etc.) a navigation capability will be specified for aircraft operating in that area. Preferential treatment will be given to aircraft with higher capabilities. The current VHF omni-directional range system/distance measuring equipment (VOR/DME) and non-directional beacons (NDBs) will be phased out over a modest period of time.

For precision approach and landing, instrument landing system (ILS) and GPS through differential techniques are now the subject of a debate which will be given a thorough review in the next ten years. The most likely outcome will be that ILS will remain the world standard during that time. Multi-mode receivers incorporating multiple sources of navigation signals, including INS, will continue. WAAS and EGNOS are now operational.

Surveillance

ADS-B will be the international civil system of surveillance, initially in en route airspace but eventually in oceanic airspace. It will supplement secondary surveillance radar in high traffic density land areas, both en route and in terminal airspace. Secondary surveillance radar with modes A, C, and S will be phased out as the standard surveillance system in high traffic density en route and terminal area airspace. Primary en route surveillance radar is expected to be phased out or used by nations for only national defense purposes.

Both SSR Mode S and ADS-B will provide expanded surveillance information to the ground air traffic management operator. In addition to aircraft position, altitude, and ID number, the new ADS-B system will provide heading, intended path (e.g., next waypoints), and wind speed/temperature. Development of airborne surveillance systems for collision avoidance using ADS-B as a back-up to ATC will continue. This would include both traffic collision avoidance systems (TCASs) and new trajectory-based systems as they evolve.

Automation

Today automation represents the efforts of civil aviation agencies to lessen the workload of air traffic controllers in congested airspace. However, automation is difficult to quantify as a field or discipline. In Europe, the challenge includes the integration of multiple ATC systems across both geographic distances and language barriers. The US now has harmonization accomplished; however, the sheer task of automating the world's largest ATC system is compelling. In many countries where only one or two international or domestic airports are in need of controlled airspace, automation often can be completely accomplished within the controller's airport terminal buildings and facilities.

Establishing a satellite-based ATM environment will inevitably encompass changes in air traffic control procedures. Organizations with responsibility for air traffic management and related ATC equipment are impacted. A large percentage of personnel in CNS/ATM are air traffic controllers, and any introduction or upgrading of automation redefines the functions of this workforce. Opportunities offered by automation will be both threatening and attractive to the controller workforce.

Avionics

Realizing the full benefits of satellite CNS and automation will require aircraft cockpits to become more fully instrumented to take advantage of automation for surveillance, communications, collision avoidance, weather reporting, and navigation. Approximately 17,000 commercial aircraft will need new avionics with ADS-B type datalinks integrated with GPS and satellite datalink within seven to ten years. The oceanic use of GPS is where the biggest change will first occur. New systems such as Iridium's Aireon will make use of standard ADS-B equipment, albeit with an upper surface antenna, providing significant efficiencies over the oceans.

Key Points:

- While NextGen and SESAR are the best-known examples of modernization programs, other regional efforts are well underway.
- Most of these efforts are concentrated in the core CNS sectors, as well as aircraft avionics, which is expected since harmonization standards dictate a requirement for interoperability.

2.2.3 Benefits of ATI Modernization to Stakeholders

The benefits of ATI modernization are many when considering the stakeholders involved in this industry. Because the management of civil aviation can be considered an "extended enterprise," all the stakeholders in this econometric sphere benefit. More direct routing and greater cost and time savings, if passed onto the airline passenger, will have an across-the-board benefit. The expected impact of new or more efficient services will be seen in visitor expenditures, airline expenditures, and induced downstream economic impact.

Seamless ATC airspace management will increase global system capacity and allow for greater, safer, and more efficient airline flow. Broad categories of benefits exist and manifest themselves in a myriad of ways, and include:

- Improved flight safety
- Cost savings and efficiencies
- Responsiveness to needs
- Economic and trade benefits
- Enhanced national security

The ultimate customer for improved ATC services and systems is this extended enterprise, and below the benefits are summarized by sector.

2.2.3.1 Business and Tourism Passengers

A modernized CNS/ATM will touch upon the airlines, the pilots who fly the transport aircraft, airport operations/operators, and the civil authorities who control flight. The passenger will see a broad range of improvements in services and at reduced cost. These include:

- **Lower airfare costs**. Lower fares are driven in part by airlines whose efficiency improvements have been passed through. Benefits will accrue mostly in markets where continuing airline competition places pressures on pricing. As modernization takes hold, reduced user fees to the airlines will also be passed through. Finally, airports will operate with more efficiency, providing additional possibilities for cost savings to be passed through.

- **Reduced travel time.** This will be evidenced through advanced ATM concepts such as reduced separation (more airspace and airport capacity). On long distance flights over congested airways, time savings in the air will be of direct and obvious benefit to the passenger. (Airport capacity constraints will become the real bottleneck of the 21st century.)

- **Improved on-time performance.** This is a direct benefit of improved ATM once the full benefits of satellite CNS and automation take hold.

- **Enhanced safety.** This will be a byproduct of reduced pilot workload, less time in the air, and streamlined air traffic control services.

2.2.3.2 Commercial Airlines

The economic benefits of improved CNS/ATM will be profound for commercial airlines. The principal elements of this are:

- **Reduced flying times.** Aircraft will be able to fly the shortest routes at the most fuel-efficient altitudes, resulting in reduced flying times and fuel consumption. In the future, standardization and the increased use of space-based CNS systems will result in lower equipment and training costs because airlines will carry fewer types of avionics on-board. Savings will also be earned through flexible dynamic routing and even reduced communications costs.

- **Reduced in-air delays.** Users, including civil and military aircraft operators, experience delays in scheduled flights or are constrained to less than optimal or efficient aircraft operations. For large air carriers, small inefficiencies can lead to substantial cost penalties in fuel or labor. For example, United Airlines reported that a ten-minute savings per aircraft on its Pacific routes can save three percent of operating costs, amounting to some $75 million per year in cost savings.

- **Reduced fuel reserves**. Air carriers can only justify the investment required to install upgraded CNS when the benefits are greater than the costs, and the civil aviation agencies cannot justify the facilities and equipment programs unless a sufficient number of operators are equipped. One possible solution is to reduce the operators' regulatory fuel reserve requirements through innovative use of CNS capabilities. Incentives for cutover will need to be implemented to entice most or all airspace users to invest in necessary equipment. For example, the US and certain EU countries might reduce fuel reserve requirements for international flights as a way of inducing carriers to install satellite-based navigation equipment and to encourage satellite-based ATC programs.

- Fuel savings would arise from smaller reserve requirements. The current oceanic reserve requirement is ten percent of planned en route fuel burn. A 50 percent reduction in fuel reserves would amount to a savings of 8,000 pounds on a 747 on an eight-hour flight. This capability, coupled with timely upper air forecasts, can be used to justify major reductions in international fuel reserves. Savings of this magnitude can quickly pay for CNS avionics equipment. It is also possible to reduce the reserves for domestic operations due to satellite-based capacity enhancements, lower landing minima, and improved upper air wind and weather forecasts.

- **Airport access**. Satellite CNS will permit aircraft equipped with modern avionics to fly into airfields that today, due to instrumented approach limitations (lack of equipment), are inaccessible. New markets can thus be served.

2.2.3.3 Commercial/Professional Pilots

Pilots, in their desire to ensure the safety of passengers and the aircraft they fly, will benefit from many aspects of a modernized CNS/ATM, including:

- **Increased safety.** With modernized CNS/ATM, the pilot will be able to avoid collisions through better and less ambiguous traffic management and automation systems.
- **Timely flight information.** For example, improved weather information and its real-time accessibility through high speed datalinks will be provided.
- **Simplified procedures.** Flying in newer modes of operation will be possible, with more simplified cockpit procedures and less pilot workload.

2.2.3.4 Air Traffic Controllers and ATS Personnel

This stakeholder group has a profound impact upon the air transport industry and, to an extent, holds the industry hostage to improved efficiencies and safety. Benefits to this group include:

- **Simplified procedures.** Controller workload will be reduced as automation takes hold and as terminal area procedures (air and ground) are modified to take full advantage of satellite CNS capabilities, especially in low visibility conditions.
- **Enhanced safety of passengers.** As with airline pilots, a modernized CNS/ATM will facilitate the controller's ability to predict, and therefore to avoid, collisions through better and less ambiguous traffic management and automation systems.
- **More rigorous training, with greater cross-industry benefits.** Controllers will become more technologically astute and, therefore, will be more capable of being employed in other industries.

Despite the benefits to ATCOs, however, this group perceives automation, whether for en route or terminal operation (including ground traffic control) not so much as a threat to job security but as a means by which individual controller performance can be gauged. Thus, support for automation is not strong.

2.2.3.5 ANSPs

For civil aviation organizations that run the CNS/ATM, growth in aircraft movements over time relates directly to required increases in the capacity of the ATC system to safely handle additional operations. Benefits include:

- **ATC equipment acquisition cost reductions.** Satellite CNS-based systems complete with automation capabilities and features will cost some 50 percent less to acquire than traditional ground-based navigation and surveillance systems.
- **ATC system operations and maintenance (O&M) cost reduction.** This is where large savings can be utilized to justify CNS/ATM modernization. These savings can also result in reduced costs to air carriers and the passengers they serve. O&M cost savings could amount to ten to 30 percent per year as facilities are simplified, procedures are streamlined, and the work force is downsized accordingly.
- **Reduced risk of system development.** Sensor fusion and automation become simplified with satellite CNS; thus the risk of system development failure, such as that demonstrated with the FAA's Advanced Automation System (AAS), can be minimized. Benefiting from progressive technologies developed in the US and in Western Europe, most other Western countries and emerging nations are modernizing with comparable system performances to those of major countries, but at a lower cost and tech-

nical risk of failure. It is not uncommon for a turnkey system of sensors, communications and automation equipment to be fully commissioned in less than three years from the date of contract award.

2.2.3.6 General Aviation (GA)

The general aviation community both welcomes and fears the impact of new CNS/ATM procedures and equipment costs. Aspects of CNS/ATM modernization will take some time to be experienced for the general aviation pilot, however.

- **Safety benefits.** General aviation will perhaps enjoy the higher levels of safety that new CNS/ATM technologies (and their related operating procedures) will bring. Over the near term, a serious operator can benefit from some of the latest navigation or communications gear. The GA community has been concerned about the proliferation of various navigation and landing aids in recent years. GPS offers “the best buy” in terms of required on-board equipment, as well as minimal ground station requirements. Flight safety will improve.

- **Cost savings.** With general aviation trending more toward all-weather flight and instrument flight rules (IFR) conditions, technologies such as GPS, WAAS, and related navigation or communications equipment will be affordable. At a 1993 landing systems conference held in Geneva, the International Council of Aircraft Owner and Pilot Associations (ICAOPA) stated that “because of the cost of multiple systems a direct transition from ILS to GPS, bypassing MLS, would be general aviation’s favored course of action.” Additionally, fuel savings will be significantly reduced.

In the US today, the FAA is exploring the possibility of supporting the development of a multi-mode navigation and flight advisory system comprising RAIM-based (receive autonomous integrity monitoring) GPS, WAAS, or DGPS, inertial sensors (for navigation-out), cockpit flight recorder, and airway database to provide waypoint information. Economic studies have pointed to the fact that airway facilities (e.g. VOR, VHF ground communications) would need to be maintained at a cost of some $80 million annually just to satisfy the GA user community. The FAA may be better served to legislate tax breaks for, and then mandate, upgrades using this FAA-developed equipment. This program concept faces stiff opposition from avionics manufacturers as well as the general aviation community and may take years to overcome.

2.2.3.7 Military Operations

The diverse aspects of military flight operations in the modernized ATM order will require that civil and military facilities be equipped and staffed to provide compatible service. In many developed countries, civil authorities control military flight operations in peacetime. Elsewhere, developing countries manage airspace and air traffic services through military ATC facilities staffed by air force controllers. As found in the US and in Europe, responsibility is often shared.

An important consideration of a modernized CNS/ATM is that special military needs are fully accommodated by the airspace system, and thus the military’s special use airspace and procedures need to be compatible with the civil component. In many countries, airspace is being redesigned to accommodate the so-called “dual-use” imperatives. Most nations’ military and commercial interests are best served by making optimum use of shared infrastructure, a more cost-effective means than dedicated facilities. Airspace is an important element of any country’s economic and trade advantage and needs to be tailored for maximum commercial advantage, without compromising national security.

In general terms, the military will derive benefits both directly and indirectly from a modernized CNS/ATM structure, whose technologies and procedures utilize advanced technologies and automation systems. For example:

- **Safety and efficiency of flight.** Directly, the military fleets will benefit from better, safer, and more efficient flight operations (similar to the benefits to be enjoyed by commercial carriers). Many air forces will be capable of using commercial avionics equipment, perhaps augmented with secure HF or VHF voice and data communications.

- **Dynamic airspace allocation.** Automation can handle complex and time-varying airspace allocation procedures and may dynamically allocate special use airspace while at all times segregating military and commercial aircraft as needed to ensure safety.

- **Increased national security.** Indirectly, a modernized CNS/ATM utilizing satellite CNS, ATM, automation, and advanced air traffic procedures will contribute to the monitoring of a nation's borders and flight corridors, helping to make air sovereignty more assured, and increasing the ability of civil aviation authorities to conduct regional operations through harmonized equipment and procedures.

The interwoven military and civil air traffic systems found in many countries have compelling integration problems. In US airspace and its territories, for example, the US Department of Defense (DOD) operates over 24,000 fixed-wing and helicopter aircraft and handles over two million civil aircraft operations per year and 20 million military aircraft operations. A variety of military operations designed to meet training, aerial refueling, and test and evaluation goals require special use airspace. These airspace requirements necessitate close coordination between the FAA and military organizations to optimize airspace use by civil and military users. The FAA provides approach control services for approximately one-half of the military airfields in the US; the DOD provides service to 218 civilian airfields. The DOD provides and operates almost 300 ATC facilities with approximately 6,400 controllers; the FAA operates about 600 ATC facilities with approximately 18,000 controllers. Thus, close integration of military and civil plans is compulsory.

2.2.3.8 Airport Authorities and Owners

Airlines and airports constantly work to increase capacity, and the recent trend in capacity expansion continues to underline the emergence of a more robust and competitive industry. Major problems are looming on the horizon, however.

Besides the obvious fact that modernized CNS/ATM comprising satellite CNS provides the capability to navigate between any two points on the globe using a common system, one of the greatest economic potentials will occur in the form of differential GPS at the local level. The implications are compelling if one stops to consider the economic benefits that nations can achieve if most of their airports and landing fields are capable of supporting Category I/II/III aviation operations. Consider the following benefits:

- **Better utilization of existing capacity**. Large airport development projects are very costly, primarily due to land acquisition and development issues. ICAO estimates that within the next 15 years over $350 billion will have to be spent on new airport construction worldwide to meet future air traffic growth requirements. It takes an average of ten years to plan, design, and build additional runways at large airport facilities because of land costs, political concerns, and environmental issues. Space for additional runways may not even be available in most cases, which leads to an even more costly proposition: the development of offshore airports.

- **Aircraft mix.** Additionally, the variable mix of aircraft operations can also have a great impact on capacity. For example, at many airports general aviation, regional commuters, and domestic and international air traffic operate from crossing or parallel runways which places even greater demands on congested terminal airspace and runways.

- **Increased use of small airports.** Therefore, the use of satellite CNS will allow smaller regional airfields to accommodate increases in traffic demands at a fraction of the cost of expanding existing large airport facilities. Governments and civil aviation authorities will recognize the use of these smaller airfields as a cost-effective way to cope with anticipated traffic growth.

- **Small airport utilization.** Smaller local airports in the vicinity of major metropolitan areas will be able to attract regional air carriers because of the capacity crunch and their newly acquired instrument approach capabilities. Trunkline carriers will still continue to handle most of the traffic, especially on direct inter-city routes. However, the network of feeder and commuter operations that link hundreds of smaller cities to each other as well as to the hub airports will dramatically increase.

  The use of smaller airports by "commuters" will help alleviate some of the congestion problems at the larger hubs, such as obtaining take-off slots. Inadequate availability of take-off slots not only adds to airport and air traffic congestion, but also creates barriers for the introduction of new routes and services. Establishing new routes is difficult for airlines and, as a result, most major airline activity has focused on increasing the frequencies on existing routes to meet traffic demand.

  Currently, airlines have been able to gain additional slots by rearranging schedules to transfer less busy services to off-peak periods, which release peak-time slots for more profitable operations. Coupled with continued liberalization measures, differential GNSS (DGNSS) will allow the use of smaller airfields, which will reduce barriers to the creation of new air routes and corresponding services.

  Helicopter operations. In addition to expanded service at regional airfields, DGNSS technology, in the long-term, will also play a key role in the concept, development, and construction of vertiports. Currently, vertiports function primarily as landing platforms on offshore oil rigs, medical emergency sites, and limited passenger transportation facilities between major airports located in close proximity. Vertiport services have been limited because most of these facilities do not have precision instrument approaches. Extensive use of vertiports will create an even greater network of commuter and feeder operations, extending the business network from downtown major metropolitan areas to suburban areas. Even oil and gas service areas and remote rural areas, including rough terrain such as mountainous and jungle areas, will be well connected to the aviation infrastructure.

2.2.3.9 National Governments

As the representative constituents of a nation's populace, governments have much at stake with a modernized CNS/ATM infrastructure. The economic health of countries will be more assured through advanced infrastructure, particularly in areas that bolster trade and increase economic activity. Transportation infrastructure is, of course, the most important, as goods, services, and trade can only be delivered through the transportation system.

- **Safety and related economic benefits.** Airport and air traffic control systems provide components of the operational environment for the safe and efficient transportation of passengers and goods through the air. The relationship between efficient air traffic control and airline profitability is well established in developed countries, and is a necessary linkage when considering potential infrastructure investment in a nation's civil aviation system.

- **Infrastructure spin-offs to other industries**. A modern ATC system will help many countries in generating economic activity through airplane manufacturing, airline operations, airport construction, and ATC equipment manufacturing.

- **Trade benefits.** Air transport is an integral tool for conducting much of the world's business, a foundation for the tourism industry, and a cost-effective means of distributing goods and services. There are thus particular benefits to be obtained from a sustained investment in air transport because of the impact of this industry on other sectors of the economy, and the world economy as a whole. Increases in national income will result from more efficient use of domestic airspace and increased access to markets of trading partners.

- **Reduced risk of infrastructure investment.** CNS/ATM and other aviation infrastructure investment is viewed as relatively low-risk with a high payback, since lending institutions can arrange payback mechanisms tied directly to air traffic service user fees. Therefore, in order to fund the modernization and growth of smaller regional airports, nations must consider such measures as corporatization and privatization of airport facilities and air navigation services in their national economic planning.

Because ATI investment will compete with other infrastructure needs of nation states, economic development priorities must be revisited. A modernized CNS/ATM may well be the first technological key to help maximize the economic benefits of any nation.

As one can see, the effects of satellite CNS and automation technologies, the basic building blocks of a modern ATC system, have far-reaching economic implications, while at the same time forming a straightforward stepping-off point for many nations, particularly those of less developed economies. By developing a national infrastructure modernization strategy that stresses small airport development through this technology, countries will greatly enhance their return on infrastructure investment through more rapid economic development and greater ability to conduct domestic and international trade.

2.2.3.10 CNS/ATM Equipment Suppliers

Several very important benefits will accrue to the CNS/ATM equipment supply industry. These benefits have been carefully forecast in our study:

- **Affordability will mean expanded market opportunities.** As mentioned, ATC equipment acquisition cost reductions are significant over traditional equipment. Satellite CNS-based systems complete with automation capabilities and features will cost some 50 percent less to acquire than traditional ground-based navigation and surveillance systems. All countries will need to keep pace with the most modernized Western countries in compatible ATC systems and will, therefore, benefit from increased affordability.

- **Common standards.** Common standards will expand market opportunities since the design and manufacture of ATC products will be accepted by all states and airlines. In addition, uniform functional requirements will allow industry suppliers to better focus their research and development, and thus assure a more likely return on their investments.

  The purchasing trend today of most countries involves the use of functional specifications (as opposed to detail design documents) that encourage the use of commercial-type equipment. For example, most recently issued international tenders for automation systems have specified the use of open system architecture based on commercial software and hardware standards. This encourages innovation and makes it very difficult for any one manufacturer to impose its standards upon the global market.

- **Reduced risk of system development.** Sensor fusion and automation become simplified with satellite CNS; thus, the risk of system development failure can be minimized. For vendors this will be an important consideration.

Key Points:

- Each stakeholder within the CNS/ATM supply chain has a distinct interest in the outcome of ATI programs.

- Most of the benefits and interests are concentrated in maximizing resources considered most precious: time (for passengers, ATC employees, and operators), revenue/cost (suppliers, operators); and certainty (all).

2.3 Policy Trends in Global and Regional CNS/ATM Programs

CNS/ATM is the procedural and systems approach used globally to control the routing of aircraft from one airport to another. Because air transport is critical to each country's economy, the importance of modernization is one of international concern. This is because global CNS/ATM increasingly does not meet the needs of a rapidly growing air transportation industry.

This section deals with the broad institutional and policy issues of existing and planned CNS/ATM infrastructure and begins with a review of the current air traffic systems spanning most of the world.

2.3.1 Existing CNS/ATM Infrastructure

In general terms, the air traffic control system widely in use today revolves around 1950s-era architecture based upon technologies and capabilities largely in use at that time to handle modest airspace capacity. While the air traffic control system in many countries is safe, it cannot handle current and projected demand adequately or efficiently, a construct which, over the long-term, will lead to diminished safety and quality of flying.

2.3.1.1 History and Perspective

In the beginning of aviation, during World War I, pilots were clearly capable of exercising a "see and avoid" procedure; aircraft-to-aircraft separation was their entire responsibility. As air traffic expanded in the late 1920s, airlines such as Pan American, Lufthansa, and British Overseas Airways established voice-only air traffic control procedures with their pilots to track their aircraft and to provide their pilots with the latest weather conditions for severe weather avoidance and landing. Later variations led to pooling of traffic and flight service information responsibilities among airlines.

An important feature of civil air navigation since World War II and its international genesis, the 1944 Chicago Conference (establishing ICAO), subjected commercial and general aviation aircraft to orderly and procedure/rule-based flow control in busy airways and around congested airfields where sequencing of landings and take-offs at airports would permit maximum safe utilization of runways.

In pursuit of these objectives, ATC relied heavily at first upon primary radar and voice communications with pilots. Then, specific purpose radars evolved for airfield and runway control, approach control, surveillance of the airways and, eventually, control of taxiway and apron traffic. As traffic intensified, voice communications alone were incapable of providing adequate means of identifying a blip on the air traffic controller's screen and, because of national security issues, secondary surveillance radar, identification friend or foe (IFF) was needed. Transponders were introduced as a means of augmenting voice identification and to assist in automating ATC procedures. Today, Mode S transponders provide digital data communications capabilities between pilots and ground controllers without unnecessarily burdening voice communications.

Routes, Hand-offs, Duties

Within the ATC structure, each controller is generally responsible for a small segment of airspace. An aircraft is "passed" from one controller to another as it progresses on its flight plan. As an aircraft enters the sector, the controller must assure separation between all aircraft within that sector. This function is dependent upon the controller's ability to project the likely future trajectory of each aircraft in the controller's control area, and to foresee and resolve conflicts in real time. Traffic is linearized, that is, fixed altitudes and routes are provided through each sector, which helps the controller to know and visualize what each aircraft is going to do and allows the controller to assure that separation is maintained. Each controller uses a separate radio frequency which requires coordination with the pilot when switching.

The air traffic controller has a duty to avoid conflicts and is, without doubt, under enormous work pressure. Not only is safety paramount in the controller's mind, but the ATC computer is programmed to automatically report when the separation minima is lost. ICAO and national civil aviation authorities agree that multiple occurrences of the violation of this separation may require a reassessment of the qualifications of a given controller. Because of this fact, and the potential for controllers to lose their jobs, controllers are very conservative about the definition of separation and often space aircraft farther apart than required.

Aircraft Separation

Today, the operational ATC system in many parts of the world is largely viewed as a collision avoidance system. Maintaining aircraft separation is the means by which collisions can be avoided. In the airspace of more modern air traffic areas such as Europe, the US, or Australia, where radar surveillance, better communications by VHF or other means, and ground-based VOR navigation are used, separation criteria is a function of the sustainable workload of controllers, not aircraft performance.

Separation today is generally conducted in two of the four dimensions possible — latitude and longitude — while relegating altitude and time as secondary considerations. This situation arose from the 1950s procedures implemented with the navigation aids available at the time.

Air traffic controllers exercise positive control over the aircraft through constant surveillance and control by radar and radio contact. The potential for aircraft meeting within a set horizontal separation of five miles must be avoided. To prevent the protective bubble of one aircraft overlapping with another, the controller must identify the conflict 40 to 50 miles from its potential occurrence and decide a resolution to avoid loss of separation.

The control methodology assures separation of aircraft and makes it the air traffic controller's responsibility. Although safe, this system has no flexibility and is inefficient in its use of airspace.

Airspace Categorization

The prevailing airspace architecture in use around the world today divides airspace into two general categories: controlled and uncontrolled. The primary difference between controlled and uncontrolled airspace is that ATC separation services are offered only to pilots operating in controlled airspace. Services provided to aircraft flying in uncontrolled airspace are on a workload-permitted basis.

This division enhances the safety and efficiency of an air traffic control system. The type of ATC service air traffic controllers can provide to commercial and general aviation (usually thought of as IFR and VFR pilots) is dependent on the category in which the aircraft is operating. Furthermore, pilot requirements for flying into different areas depend on the type of airspace.

Uncontrolled Airspace

Uncontrolled airspace is airspace in which the civil aviation authority will not provide ATC clearance or separation services to any aircraft, whether IFR or VFR. Flight in uncontrolled airspace has specific regulations placing the burden of separation on the pilot. Most of the world's airspace below a few thousand feet is uncontrolled. The majority of uncontrolled airspace in the US is located away from airports below 1,200 feet above ground level.

Controlled Airspace - General

In controlled airspace the civil aviation agency or air navigation service provides both ATC clearance or separation services and additional ATC services to pilots. However, it is dependent on the type of flight and the category of airspace involved in which the pilot may or may not be required to use ATC services or even contact ATC facilities.

Generally speaking, if a pilot is in controlled airspace flying IFR, the pilot must receive ATC services, whereas contact with ATC is not required if the pilot is flying VFR in a controlled airspace and is not entering special use airspace.

Controlled Airspace - VFR Flights

Pilots must comply with special regulations of the civil aviation agency in order to fly VFR in a controlled airspace. For example, the pilot must provide his own separation from other VFR and IFR aircraft. Certain minima are designed to maximize the chances that a VFR pilot will see and avoid other VFR and IFR aircraft. If the pilot is unable to comply with these minima, VFR flight cannot be legally conducted in controlled airspace. The pilot is required to either land or receive an IFR or a special VFR clearance to legally continue the flight. A special VFR clearance will allow the pilot to fly in certain weather conditions that do not meet minimum VFR criteria. Designated altitudes are assigned to minimize the potential for midair collisions between two aircraft flying in opposite directions.

Controlled Airspace - IFR Flights

Air traffic controllers are required to separate IFR and VFR aircraft within controlled airspace using the most stringent procedures. Regardless of services provided by controllers, both IFR and VFR pilots are responsible for seeing and avoiding non-participating aircraft which may be operating in the controlled airspace.

Aircraft Flow Management

Flow control is another methodology designed to minimize route congestion by keeping an aircraft on the ground before takeoff, rather than having it hold in flight. Flow control effectively meters aircraft into and out of the airways. Control rests with the CAAs and, while it has certain efficiencies, aircraft flow management adds to the total cost of flying and is a significant cost factor to airlines.

Aircraft flow management most often must be approached on a regional basis, along with complex system requirements to deal with added factors such as multiple state participation, etc. For example:

- In the US, the FAA has established a major central flow control facility to automate and coordinate the activities of flow management. There are from 4,000 to 6,000 aircraft operating in the US NAS during peak periods, and this equates to approximately 50,000 aircraft operations per day. The role of the Air Traffic Control System Command Center (ATCSCC) is to manage this flow of air traffic within the continental US. The ATCSCC has been operational since 1994 and is located in one of the largest and most sophisticated facilities of its kind.

  The ATCSCC regulates air traffic when weather, equipment, runway closures, or other impacting conditions place stress on the NAS. In these instances, traffic management personnel take action to modify traffic demands in order to remain within system capacity. This is accomplished in cooperation with: 1) airline personnel; 2) traffic management personnel at affected facilities; and, 3) air traffic controllers at affected facilities. This helps minimize delays and congestion and maximizes the overall use of the NAS, thereby ensuring safe and efficient air travel within the US.

- EUROCONTROL is the European Organization for the Safety of Air Navigation. Founded in 1963, it is an international, pan-European entity working for seamless, pan-European air traffic management. Headquartered in Brussels, EUROCONTROL is a civil organization and currently has 39 member states.

  EUROCONTROL coordinates and plans air traffic control for all of Europe. This involves working with national authorities, air navigation service providers, civil and military airspace users, airports, and other organizations. Its activities involve all gate-to-gate air navigation service operations: strategic and tactical flow management, controller training, regional control of airspace, safety-proofed technologies and procedures, and collection of air navigation charges. All IFR flight plans are tracked by a CFMU (central flow management unit). Each airport and air traffic control sector has a published maximum capacity. When capacity is exceeded, measures are taken to reduce the traffic, which is termed regulation. The aim is to utilize capacity effectively, keeping the average delay as low as possible, while ensuring capacity is not exceeded.

As a (highly simplified) example, if two flights are scheduled to arrive at an airport at exactly the same time, and the airport can handle one aircraft every five minutes, one aircraft may be assigned a delay to ensure that it arrives five minutes after the first. Similarly, the first aircraft will be required to depart on schedule. This way, the second aircraft will not need to endure a lengthy wait in the air. In practice, the process is much more complex and highly computerized. One aircraft may be subject to several regulations at the same time. For example, a flight from Amsterdam to Paris may be regulated both by limited capacity at Paris as well as by limited capacity in Belgian airspace.

In some cases, it may be possible to avoid delay by taking a different route. For instance, if Belgian airspace was the only regulation for the flight in the previous example, changing the route to avoid Belgium and going via Germany instead might allow a flight to depart without delay, although the route might be a bit longer. In many cases, airlines authorize the CFMU to make changes in a flight's route to avoid delay. Certain flights are exempt from regulation, for instance, time-critical flights carrying human organs for transplantation. If such flights are scheduled, regular traffic will be delayed instead.

If an airport is completely closed unexpectedly (for instance, because the only runway is blocked), a zero rate may be set for a certain time period (e.g. until the runway is expected to be reopened), which will cause all inbound flights to be issued a delay that will cause them to arrive after the reopening time. Flights already en route would either enter the holding or divert to an alternate airport.

Flow control facilities are currently under development in other areas of the world where congestion is on the rise, including the Far East and South America.

2.3.1.2 Inefficiencies and General Economic Impacts

A harsh economic analysis of air transport points to the fact that it is not the cost of loss of aircraft or lives due to the (rare) ground or (rarer) mid-air collisions that occur, but the cost of providing CNS/ATM procedures that maintain these enviable standards. There is no lack of airspace in the world; congestion is largely a by-product of the existing ATC architecture. The implementation of air traffic corridors, levels, and control area procedures renders vast areas of the world's airspace unusable to air commerce. Today, an ATC system is designed to force a majority of air traffic into tightly defined corridors or areas where it can be "controlled" by air traffic controllers. In addition, the current methodology forces the airspace to fit the least capable aircraft.

To confirm this, one need only stand in the control tower at Heathrow or O'Hare airports, two of the world's busiest, and realize how empty the sky is. The queue to land at O'Hare begins on the ground at Heathrow (and elsewhere). Presently, by most standards, an aircraft flying over the North Atlantic is deemed to occupy a block of space 2,000 feet high, 60 nautical miles (NM) wide and ten minutes (or 60 NM) long, and any invasion of that space is regarded as potentially hazardous. It is possible to quantify the cost of inefficiency of the world's present ATC system by examining:

- Cost to airlines and passengers of delays, diversions, and non-optimal routing of flights.
- Price of providing existing ATC services.
- Cost to economies of world due to loss of efficiency (i.e., tourism industry costs).

The price of ATC services alone in the EU countries exceeds $15 per passenger per flying hour. Airway routing itself adds seven percent to the great circle distance in Europe, and is greater in the US. On many routes around the world, preferred flight level is refused more times than is approved, adding substantially to fuel consumption. Required thrust varies linearly with weight, and millions of tons of fuel are consumed annually to carry large fuel reserves for ATC contingencies that arise from unfavorable clearances or terminal area delays.

Key Points:

- Due to legacy constraints in technology and procedures, inefficiencies in current airspace management create additional layers of costs for both providers and users of air traffic systems.
- These inefficiencies represent an opportunity for improvement in capabilities and further investment in ATM services.

2.3.2 CNS/ATM Modernization Programs and Policy Implications by Concept

As detailed early in this chapter, ATC is an infrastructure item, and modernization as such must consider the role of the supporting environment as well as other infrastructures (highways, electricity, telecommunications, etc.). For example, a country's national economic climate should be conducive to an efficient allocation of resources, thereby reducing the potential for investment in infrastructure to take resources away from more productive investment. Also, CNS/ATM infrastructure projects can only raise return to other resources when there is a sufficient complement of other necessary resources available. For example, ATC modernization cannot occur unless a competent (high speed, redundant, fail-safe, etc.) telecommunications system is available.

2.3.2.1 Evolving CNS/ATM Concepts Shaping Modernization Policies

The world clearly needs to implement a CNS/ATM system compatible with the needs of the future. These concepts raise far-reaching policy questions spanning areas of sovereignty, finance, and airspace control, to name a few.

Futuristic concepts will require the extensive use of:

- Advanced automation concepts to reduce both controller and pilot workload.
- Satellite CNS to alleviate the constraints of terrestrial airway facility flexibility, capacity, operations, and maintenance costs.
- Advanced cockpits, incorporating the latest in automation, navigation, and communications avionics, and concomitant training.

It is important to note that because technologies for these concepts to work are just now being fielded, it will be many years before most of these notions could be implemented globally.

RNP and Tunnels in Space

Required navigation performance (RNP) is a type of performance-based navigation (PBN) that allows an aircraft to fly a specific path between two three-dimensionally defined points in space. RNAV and RNP systems are fundamentally similar. The key difference between them is the requirement for on-board performance monitoring and alerting. A navigation specification that includes a requirement for on-board navigation performance monitoring and alerting is referred to as an RNP specification. One without such a requirement is referred to as an RNAV specification.

RNP also refers to the level of performance required for a specific procedure or a specific block of airspace. An RNP of ten means that a navigation system must be able to calculate its position to within a circle with a radius of ten nautical miles. An RNP of 0.3 means the aircraft navigation system must be able to calculate its position to within a circle with a radius of three-tenths of a nautical mile. A related term, actual navigation performance

(ANP), refers to the current performance of a navigation system while RNP refers to the accuracy required for a given block of airspace or a specific instrument procedure.

Some oceanic airspace has an RNP of four or ten. The level of RNP an aircraft is capable of determines the separation required between aircraft. RNP approaches with RNP values currently down to 0.1 allow aircraft to follow precise three-dimensional curved flight paths through congested airspace, around noise sensitive areas, or through difficult terrain.

The performance monitoring and alerting requirements for RNP 4, Basic-RNP 1, and RNP APCH have common terminology and application. Each of these specifications includes requirements for the following characteristics:

- **Accuracy:** The accuracy requirement defines the 95 percent total system error (TSE) for those dimensions where an accuracy requirement is specified. The accuracy requirement is harmonized with the RNAV navigation specifications and is always equal to the accuracy value. A unique aspect of the RNP navigation specifications is that the accuracy is one of the performance characteristics that is monitored.

- **Performance monitoring:** The aircraft, or aircraft and pilot combination, is required to monitor the TSE and to provide an alert if the accuracy requirement is not met or if the probability that the TSE exceeds two times the accuracy value is larger than 10−5. To the extent operational procedures are used to satisfy this requirement, the crew procedure, equipment characteristics, and installation are evaluated for their effectiveness and equivalence.

- **Aircraft failures:** Failure of aircraft equipment is considered within airworthiness regulations. Failures are categorized by the severity of the aircraft level effect, and the system must be designed to reduce the likelihood of the failure or mitigate its effects. Both malfunction (equipment operating but not providing appropriate output) and loss of function (equipment ceases to function) are addressed. Dual system requirements are determined based on operational continuity (e.g. oceanic and remote operations). The requirements of aircraft failure characteristics are not unique to RNP navigation specifications.

- **Signal-in-space failures:** Signal-in-space characteristics of navigation signals are the responsibility of the ANSP.

The net effect of RNP navigation specifications is to provide bounding of the TSE distribution. Since path definition error is assumed to be negligible, the monitoring requirement is reduced to the other two components of TSE, i.e. flight technical error (FTE) and navigation system error (NSE). It is assumed that FTE is a stochastic process within a given flight control mode. As a result, the FTE distribution is constant over time within a given flight control mode. However, in contrast, the NSE distribution varies over time due to a number of changing characteristics, notably:

- **Selected navigation sensors:** The navigation sensors being used to estimate position, such as GNSS or DME/DME.

- **The relative geometry of the aircraft position to the supporting navigation aids:** All radio navigation aids have this basic variability, although the specific characteristics change. GNSS performance is affected by the relative geometry of the satellites compared to the aircraft. DME/DME navigation solutions are affected by the inclusion angle between the two DMEs at the aircraft (90° being optimal) and the distance to the DMEs, since the aircraft DME transponder can have increasing range errors with increasing distance.

- **Inertial reference units**: Errors increase over time since last updated.

- Areas of operation for RNP are described below:

- **Oceanic and remote continental:** Oceanic and remote continental airspace is currently served by two navigation applications, RNAV 10 and RNP 4. Both rely primarily on GNSS to support the navigation element of the airspace. In the case of RNAV 10, no form of ATS surveillance is required. In the case of RNP 4, ADS-contract (ADS-C) is used.

- **Continental en route:** Continental en route airspace is currently supported by RNAV applications. RNAV 5 is used in the Middle East and European regions, but as of 2008 it is designated as B-RNAV (basic RNAV in Europe and RNP 5 in the Middle East). In the US, RNAV 2 supports en route continental airspace. At present, continental RNAV applications support airspace specifications which include radar surveillance and direct controller-to-pilot voice communications.

- **Terminal airspace arrival and departure:** Existing terminal airspace concepts, which include arrival and departure, are supported by RNAV applications. These are currently used in the European region and the US. The European terminal airspace RNAV application is known as precision RNAV (P-RNAV). Although the RNAV 1 specification shares a common navigation accuracy with P-RNAV, this regional navigation specification does not satisfy the full requirements of the RNAV 1 specification. As of 2008, the US terminal airspace application formerly known as US RNAV Type B has been aligned with the PBN concept and is now called RNAV 1. Basic RNP 1 has been developed primarily for application in non-radar, low-density terminal airspace. In future, more RNP applications are expected to be developed for both en route and terminal airspace.

- **Approach:** Approach concepts cover all segments of the instrument approach, i.e. initial, intermediate, final, and missed approach. They will increasingly call for RNP specifications requiring a navigation accuracy of 0.3 NM to 0.1 NM or lower. Typically, three sorts of RNP applications are characteristic of this phase of flight: new procedures to runways never served by an instrument procedure, procedures either replacing or serving as backup to existing instrument procedures based on different technologies, and procedures developed to enhance airport access in demanding environments (RNP APCH and RNP AR APCH). RNP approaches to 0.3 NM and 0.1 NM at Queenstown Airport in New Zealand are the primary approaches used by Qantas and Air New Zealand for both international and domestic services. Due to terrain restrictions, ILS approaches are not possible, and conventional VOR/DME approaches have descent restrictions more than 2,000 ft. above the airport level. The RNP approaches and departures follow curved paths below terrain level.

- **Special Aircraft and Aircrew Authorization Required approach:** RNP instrument approach procedures with special aircraft and aircrew authorization required (SAAAR) approach procedures build upon the performance-based NAS concept. The performance requirements to conduct an approach are defined, and aircraft are qualified against these performance requirements. Conventional obstacle evaluation areas for ground-based navigation aids are based on a predefined aircraft capability and navigation system. RNP SAAAR criteria for obstacle evaluation are flexible and designed to adapt to unique operational environments. This allows approach-specific performance requirements as necessary for an approach procedure.

  The operational requirement can include avoiding terrain and obstacles, deconflicting airspace or resolving environmental constraints. RNP approaches include capabilities that require special aircraft and aircrew authorization similar to category II/III ILS operations. All RNP SAAAR approaches have reduced lateral obstacle evaluation areas and vertical obstacle clearance surfaces predicated on the aircraft and aircrew performance requirements. When conducting an RNP SAAAR approach using a line of minima less than RNP 0.3, no single-point-of-failure can cause the loss of guidance compliant with the RNP value associated with the approach. Typically, the aircraft must have at least dual GNSS sensors, dual flight management systems, dual air data systems, dual autopilots, and a single inertial reference unit. When conducting an RNP SAAAR approach with a missed approach less than RNP 1.0, no single-point-of-failure can cause the loss of guidance compliant with the RNP value associated with a missed approach procedure. Typically, the aircraft must have at least dual GNSS sensors, dual flight management systems, dual air data systems, dual autopilots, and a single inertial reference unit.

CNS/ATM: SBAS

New space-based CNS/ATM technologies will greatly reduce horizontal and vertical separation without impacting safety. Satellite ATM raises unique policy matters as we discuss below. ICAO calls the first types of system a satellite-based augmentation system (SBAS) as shown in Figure 2-13.

- **WAAS:** The Wide Area Augmentation System (WAAS) is a fully operational air navigation aid developed by the FAA to augment GDPGPS, with the goal of improving its accuracy, integrity, and availability. In operation for many years, WAAS is intended to enable aircraft to rely on GPS for all phases of flight, including precision approaches to any airport within its coverage area. WAAS uses a network of ground-based reference stations in North America and Hawaii to measure small variations in the GPS satellites' signals in the western hemisphere. Measurements from the reference stations are routed to master stations, which queue the received deviation correction (DC) and send the correction messages to geostationary WAAS satellites in a timely manner (every five seconds or less). Those satellites broadcast the correction messages back to earth, where WAAS-enabled GPS receivers, manufactured by most GPS avionics and GPS positioning companies, use the corrections while computing their positions to improve accuracy.

  WAAS addresses the navigation problem, providing highly accurate positioning that is extremely easy to use, for the cost of a single receiver installed on the aircraft. Ground and space-based infrastructure is relatively limited, and no on-airport system is needed. WAAS allows a precision approach to be published for any airport, for the cost of developing the procedures and publishing the new approach plates. This means that almost any airport can have a precision approach, and the cost of implementation is dramatically reduced. Additionally, WAAS works just as well between airports. This allows the aircraft to fly directly from one airport to another, as opposed to following routes based on ground-based signals. This can cut route distances considerably in some cases, saving both time and fuel.

  In addition, because of its ability to provide information on the accuracy of each GPS satellite's information, aircraft equipped with WAAS are permitted to fly at lower en route altitudes than was possible with ground-based systems, which were often blocked by terrain of varying elevation. This enables pilots to safely fly at lower altitudes, not having to rely on ground-based systems. For unpressurized aircraft, this conserves oxygen and enhances safety. The above benefits create not only convenience, but also have the potential to generate significant cost savings.

- **EGNOS:** European Geostationary Navigation Overlay Service (EGNOS) is a satellite-based augmentation system (SBAS) developed by the European Space Agency, the European Commission, and EUROCONTROL. It supplements the GPS, GLONASS, and Galileo systems by reporting on the reliability and accuracy of their signals. The official start of operations was announced by the European Commission in October 2009. According to specifications, horizontal position accuracy should be better than seven meters. In practice, the horizontal position accuracy is at the meter level.

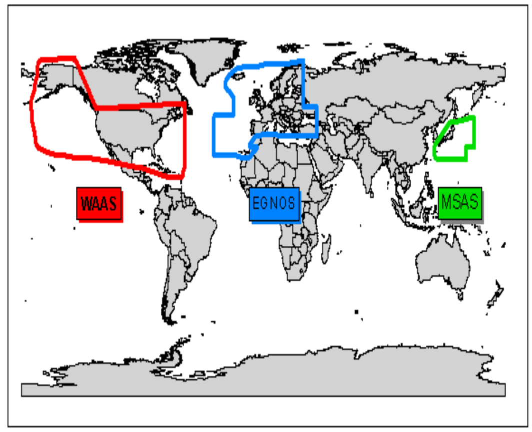
The EGNOS system consists of three geostationary satellites and a network of ground stations. The system started its initial operations in July 2005, showing outstanding performance in terms of accuracy (better than two meters) and availability (above 99 percent). It was certified for use in safety-of-life applications in March 2011. Since July 2005, EGNOS has been broadcasting a continuous signal. Similar to WAAS, EGNOS is mostly designed for aviation users who enjoy unperturbed reception of direct signals from geostationary satellites up to very high latitudes. The use of EGNOS on the ground, especially in urban areas, is limited due to relatively low elevation of geostationary satellites: about 30° above the horizon in central Europe and much less in northern Europe. To address this problem, in 2002 ESA released SISNeT, an internet service designed for continuous delivery of EGNOS signals to ground users. The first experimental SISNeT receiver was created by the Finnish Geodetic Institute. Commercial SISNeT receivers have been developed by Septentrio.

- **MSAS:** The Japanese Multi-functional Satellite Augmentation System (MSAS), is an SBAS designed to supplement the GPS system by reporting (and then improving) on the reliability and accuracy of those signals. MSAS for aviation use was commissioned in September 2007. Chief among the MSAS beneficiaries will be aircraft operating transoceanic routes across the Pacific. The improved navigation accuracy and associated communications links will allow planes to operate closer together along the most traveled routes.

  In addition to the GPS navigation data, MSAS will provide datalinks to and from ATC control centers and enable the automatic transmission of aircraft locations to controllers when aircraft are out of range of ground-based ATC radars — a feature known as automatic dependent surveillance. Besides the L-band GPS broadcasts, MTSAT provides voice and data communications over Ku- and Ka-band frequencies. MSAS operates in fashion similar to the WAAS and provides a comparable service to EGNOS.

Figure 2-13

SBASs



Source: European Space Agency

- **GAGAN:** The GPS-aided geo-augmented navigation system (GAGAN) is a planned implementation of an SBAS by the Airports Authority of the Indian government (AAI). It is a system to improve the accuracy of a GNSS receiver by providing reference signals. The AAI's efforts towards implementation of operational SBAS can be viewed as the first step towards introduction of a modern communications navigation, surveillance/air traffic management system over Indian airspace.

- The project involves establishment of 15 Indian reference stations, three Indian navigation land uplink stations, three Indian mission control centers, and installation of all associated software and communication links. GAGAN is planned for operational status by the year 2014. It will be able to help pilots navigate in Indian airspace by an accuracy of three miles. This will be helpful for landing aircraft in tough weather and terrain like Mangalore Airport and Leh. A flight-management system based on GAGAN will then be poised to save operators time and money by managing climb, descent, and engine performance profiles.

- The FMS will improve efficiency and flexibility by increasing the use of operator-preferred trajectories. It will improve airport and airspace access in all weather conditions, and provide the ability to meet environmental and obstacle clearance constraints. It will also enhance reliability and reduce delays by defining more precise terminal area procedures that feature parallel routes and environmentally- optimized airspace corridors. GAGAN will increase safety by using a three-dimensional approach operation with course guidance to the runway, which will reduce the risk of controlled flight into terrain. Also, GAGAN will offer high position accuracies over a wide geographical area like Indian airspace. These position accuracies will be simultaneously available to 80 civilian and more than 200 non-civilian airports and airfields and will facilitate an increase in the number of airports to 500 as planned. These position accuracies can be further enhanced with ground-based augmentation systems.

CNS/ATM: Space Based Surveillance – Aireon and ALAS

- **Iridium/Aireon:** Iridium Communications, Inc. and an ANSP consortium led by NAV CANADA recently formed Aireon to deploy and operate a global satellite-based aviation monitoring service utilizing ADS-B technology. The Aireon system will offer a critical global extension of current and proposed ADS-B terrestrial systems, providing surveillance coverage over the oceans, the poles, and remote regions. This will include commercial aircraft surveillance in a number of regions that would not otherwise have coverage, which should also help accelerate the global adoption of ADS-B systems.

- Aireon will deploy a space-based ADS-B aviation monitoring service to complement the terrestrial component of ADS-B systems worldwide by expanding its reach to global coverage. An ADS-B payload receiver will be hosted on each of the 81 satellites in Iridium's next-generation satellite constellation (Iridium NEXT), which is scheduled to be launched from 2015 through 2017. The Aireon system uses 1090ES and would be able to cost-effectively collect and process commercial aircraft positional information embedded in the ADS-B message for all transoceanic and transpolar routes, as well as for travel across remote or underdeveloped regions of the world. This positional information is expected to be transmitted in near real-time to ground-based regional ATC centers.

- Policy implications of Aireon for ANSPs and commercial CNS/ATM developers are many. For the first time ever, ANSPs around the globe will be able to continuously track aircraft anywhere in the world. NAV CANADA, whose participation is subject to the completion of formal agreements in the near future (Fall 2012), intends to be Aireon's first customer. Aireon will enable fully global and continuous space-based monitoring and control of aircraft, even over oceans and remote regions where it is not currently possible. As a result of Aireon's new service, commercial airline operations will be more efficient, safer, and more environmentally friendly.

- **Globalstar/ALAS:** In June 2012, Alaska-based ADS-B Technologies announced the results of its first tests of its ADS-B Link Automation System (ALAS). The April tests involved successful tracking of two aircraft a few hundred feet off the ground in a 4,000-foot deep mountain pass, sometimes flying in close formation. The ALAS system will use the Globalstar constellation of 24 low-earth-orbit satellites and will work with both of the signal formats in use by the ADS-B system: 1090ES and UAT. ALAS has been under development since 2009, and the company says it expects full certification by 2014. The second-generation satellites are expected to provide Globalstar customers with satellite voice and data services until at least 2025.

- Two significant points of difference between Aireon and ALAS are the way each uses satellites and the signal formats. Aireon is offering service only for 1090 MHz Extended Squitter users, which includes all airlines, while ALAS offers both 1090ES and the UAT format preferred by most general aviation aircraft operators. ALAS requires no payloads on the satellite constellation and plans to use the Globalstar satellites like mirrors, simply retransmitting the signal received from aircraft to a Globalstar ground station.

CNS/ATM: Navigation – GPS, GLONASS, Galileo, and BieDou

Numerous nationally or regionally sponsored navigation solutions, and their associated policy implications, are discussed in this section.

- **GPS:** The Global Positioning System (GPS) is a space-based satellite navigation system that provides location and time information in all weather, anywhere on or near the earth, where there is an unobstructed line of sight to four or more GPS satellites. It is maintained by the US government and is freely accessible to anyone with a GPS receiver.

- Advances in technology and new demands on the existing system have now led to efforts to modernize the GPS system and implement the next generation of GPS III satellites. The GPS program provides critical capabilities to military, civil, and commercial users around the world. In addition, GPS is the backbone for modernizing the global air traffic system. Advances in technology and new demands on the existing GPS system have now led to efforts to modernize the system and implement the next generation of GPS III satellites. Over the last decade, the US has implemented several improvements to the GPS service, including new signals for civil use and increased accuracy and integrity for all users, all while maintaining compatibility with existing GPS equipment.

- GPS is owned and operated by the US government as a national and, increasingly, global resource. The Department of Defense is the steward of GPS, while the National Space-Based Positioning, Navigation, and Timing Executive Committee was established by presidential directive in 2004 to advise and coordinate federal departments and agencies on matters concerning the GPS and related systems. The executive committee is chaired jointly by the deputy secretaries of Defense and Transportation. Its membership includes equivalent-level officials from the Departments of State, Commerce, and Homeland Security, the Joint Chiefs of Staff, and NASA. Components of the Executive Office of the President participate as observers to the executive committee, and the FCC chairman participates as a liaison.

  By policy, the DOD is now required by law to "maintain a Standard Positioning Service (as defined in the federal radio navigation plan and the standard positioning service signal specification) that will be available on a continuous, worldwide basis," and "develop measures to prevent hostile use of GPS and its augmentations without unduly disrupting or degrading civilian uses."

- In the US, GPS receivers are regulated under the Federal Communications Commission's rules. GPS receiver manufacturers design their receivers to use spectrum beyond the GPS-allocated band, a necessary requirement as the receivers must be able to absorb the Doppler effect created from receiver movement. In some cases, GPS receivers are designed to use up to 400 MHz of spectrum in either direction of the L1 frequency of 1575.42 MHz. However, as regulated under the FCC's Part 15 rules, GPS receivers are not granted or warranted protection from signals outside GPS-allocated spectrum. Recent challenges posed by LightSquared created a number of policy issues. However, GPS receiver manufacturers have argued that LightSquared's licensed spectrum of 1525 to 1559 MHz was never envisioned as being used for high-powered and high-speed wireless broadband, although there is no regulatory or legal backing of this claim.

- **GLONASS:** GLONASS is a radio-based satellite navigation system operated for the Russian government by the Russian Aerospace Defense Forces. It both complements and provides an alternative to the US GPS and is currently the only alternative navigational system in operation with global coverage and of comparable precision. By October 2011, the full orbital constellation of 24 GLONASS satellites was restored, enabling full global coverage. The GLONASS satellites' designs have undergone several upgrades, with the latest version known as GLONASS-K.

  Although the GLONASS constellation has reached global coverage, its commercialization, especially development of the user segment, has been lacking compared to the GPS system. In late 2010, there were only a handful of GLONASS receivers on the market, and few of them were meant for ordinary consumers. To improve the situation, the Russian government has begun promoting GLONASS for civilian use. For example, to improve development of the user segment, in August 2010, the Russian government announced a plan to introduce a 25 percent import duty on all GPS-capable devices, including mobile phones, unless they are compatible with GLONASS.

- In April 2012, *Rossiiskaya Gazeta*, the official print media organ for the Russian government, published a decision by the Russian Ministry of Transport to make GLONASS or GLONASS+GPS satellite navigation equipment standard for most civil airplanes and helicopters in Russia. The measure was intended to boost safety and improve air traffic control, the ministry stated. It has a six-year implementation horizon, covering new aircraft of Russian make with airworthiness certificates issued after December 2011, as well as foreign aircraft operating in Russian airspace.

- Commercial aircraft with a maximum takeoff weight of 495 kg or more are also required to have GLONASS or GLONASS+GPS navigators on board by January 2015, followed in precisely one year by general-purpose civil airplanes and helicopters with a maximum takeoff weight of 5,700 kg or more. Aircraft of international make with the same takeoff weight parameters, flown commercially in Russia by both domestic and foreign airlines, are expected to meet their deadlines between January 2017 and January 2018. The most recent decision is another in a series of decrees the Russian transportation regulator has issued over the past four years in pursuance of a 2008 federal legislation that holds all Russian passenger carriers, haulers, and shippers liable for using GLONASS or GLONASS+GPS positioning capabilities.

- **Galileo:** Galileo is a satellite navigation system currently being built by the EU and the European Space Agency (ESA). One of the aims of Galileo is to provide a high-precision positioning system upon which European nations can rely, independent of the Russian GLONASS, US GPS, and Chinese Compass systems, which can be disabled in times of war or conflict. In October 2011, the first two of four operational satellites were launched to validate the system. The next two will follow in 2012. Once this in-orbit validation (IOV) phase has been completed, additional satellites will be launched to reach initial operational capability (IOC) around mid-decade. Full completion of the 30 satellite Galileo system (27 operational + three active spares) is expected by 2019.

- The European Commission also announced that the €85 million ($104.3 million) contract for system support covering industrial services required by ESA for integration and validation of the Galileo system was awarded to Thales Alenia Space. Thales Alenia Space subcontracts performances to Astrium GmbH and security to Thales Communications. In February 2012, eight additional satellites were ordered, bringing the total to 22 full operational capability (FOC) satellites.

- Galileo is intended to provide horizontal and vertical positions measurements within one-meter precision, and better positioning services at high latitudes than other satellite positioning systems. The use of basic (low-precision) Galileo services will be free and open to users, while a high-precision capability will be available for paying commercial users and for military use.

  The Galileo system is intended primarily for civilian use, unlike the US system, which the US military runs and uses on a primary basis. Galileo will only be subject to commercial denial for military purposes in extreme circumstances. It will be available at its full precision to both civil and military users.

- **BeiDou:** The BeiDou (Compass) navigation system is a project by China to develop an independent satellite navigation system. It may refer to either one or both generations of the Chinese navigation system. The first BeiDou system, officially called BeiDou Satellite Navigation Experimental System, but known as BeiDou-1, consists of three satellites and offers limited coverage and applications. It has been offering navigation services, mainly for customers in China and neighboring regions, since 2000. The second generation of the system, known as Compass or BeiDou-2, which will be a global satellite navigation system consisting of 35 satellites, is still under construction as of Summer 2012. It became operational in China in December 2011, with ten satellites in use. It is planned to offer services to customers in the Asia-Pacific region by late 2012, and to global customers upon its completion in 2020.

2.3.2.2 ICAO Policy on CNS/ATM Systems Implementation

ICAO was created in 1944 to promote the safe and orderly development of international civil aviation throughout the world. It sets standards and regulations necessary for aviation safety, security, efficiency, and regularity, as well as for aviation environmental protection. The organization serves as the forum for cooperation in all fields of civil aviation among its 191 member states.

In continuing to fulfill its mandate under Article 44 of the *Convention on International Civil Aviation*, ICAO pursues a course of action to:

- Develop the principals and techniques of international air navigation.

- Foster the planning and development of international air transport so as to ensure the safe and orderly growth of civil aviation throughout the world.

ICAO recognized the limitations of the present terrestrial-based air traffic control systems and developed the ICAO CNS/ATM systems concept, emphasizing use of satellite technology. ICAO considers an early introduction of the new systems to be in the interest of healthy growth of international civil aviation.

Cost-Effective ICAO Policy Elements

ICAO's position is that the technical obstacles to CNS/ATM systems implementation have been overcome, and that the main challenges faced by member states are currently of an organizational and financial nature. Policy guidance in these two areas is largely in place. Moreover, most of the basic practical guidance required relating to organizational options, cost/benefit analysis, financial control, cost recovery, and financing has been developed, but will need to be reviewed and expanded as required.

Furthermore, while the cost/benefit work demonstrates the economic viability of CNS/ATM systems, states and other service providers need to develop sound business cases to convince funding institutions to invest in these systems. It is clear, therefore, that more effort needs to be made by ICAO to assist a large number of states both in implementing available guidance and in developing business cases. Inadequate organization of air navigation services operation and lack of sound financial management procedures may undermine the confidence of the financial community to provide these states with the financing required to implement CNS/ATM systems components.

The implementation and operation of major CNS/ATM systems components require, with rare exceptions, international cooperation because of the magnitude of investments involved and the capacity that will be provided. Assistance is, however, required in many regions to establish such cooperative ventures as well as other cooperative or joint ventures which can greatly benefit states.

A fundamental characteristic of CNS/ATM systems (except for airborne equipment) is that they are provided as part of the air navigation facilities and services, and hence the same basic economic principles apply to them as to other such facilities and services. What sets CNS/ATM systems apart technically from most other air navigation facilities and services is the improved technology and the extension of capacity they offer, but that is a difference in degree, not in substance. Consequently, policy guidance developed by ICAO on organizational and cost recovery aspects of air navigation services also applies to CNS/ATM systems.

CNS/ATM Design Principles

The design, implementation, and operation of all new CNS/ATM systems are required to adhere to the following principles:

- **Universal accessibility:** Accessibility without discrimination governs the provision of any ICAO-backed air navigation service provided by way of CNS/ATM systems.

- **Sovereignty, authority, and responsibility of contracting states:** Implementation of CNS/ATM systems will not infringe upon individual states' sovereignty, authority, or responsibility in the control of air navigation and the promulgation and enforcement of safety regulations. States' authority will be preserved in the coordination and control of communications and in the augmentation of satellite navigation services.

- **Responsibility and role of ICAO:** In accordance with the Convention, ICAO will continue to develop global standards, recommended practices, and procedures for CNS/ATM systems, seeking the highest practicable degree of uniformity in all matters concerned with the safety, regularity, and efficiency of air navigation. ICAO will also facilitate the provision of assistance to countries with regard to the technical, financial, and legal aspects of implementation.

- **Technical cooperation:** In the interest of a globally harmonious, coordinated implementation and early realization of the benefits to countries, users, and providers, ICAO will coordinate technical cooperation between and among countries.

- **Institutional arrangements and implementation:** Any new CNS/ATM systems will make optimum use of existing organizational structure, operated to the extent possible in accordance with existing institutional and legal regulations. Countries are encouraged to take advantage of the rationalization, integration, and harmonization of systems. It is recognized that a globally coordinated implementation, with full involvement of countries, users, and service providers through regional air navigation planning and implementation groups is the key to realizing the full benefits of satellite CNS/ATM.

- **Global Navigation Satellite System:** The GNSS should be implemented as an evolutionary progression from existing systems, GPS and GLONASS, toward an integrated GNSS over which contracting states exercise a sufficient level of control in aspects related to its use by civil aviation. ICAO will continue to explore, with users, states, and service providers, the feasibility of achieving (e.g., owning) a civil and internationally controlled GNSS.

- **Airspace organization and utilization:** CNS/ATM systems will be implemented to overcome the capacity and institutional limitations of current terrestrial ATC systems, all the while catering toward evolving global air traffic demand and user requirements for efficiency and economy while maintaining or improving margins of safety. Countries are encouraged to achieve further efficiency and economy through consolidation of facilities or services.

- **Continuity and quality of service:** Continuous availability of any CNS/ATM system, including arrangements to minimize the operational impact of unavoidable system malfunctions or failure, as well as achieve expeditious service recovery, will be assured. Quality of system service will comply with ICAO standards of system integrity and be accorded the required priority, security, and protection from interference.

- **Cost recovery:** In order to achieve a reasonable cost allocation among all users, any recovery of costs incurred in the provision of CNS/ATM systems and services will be in accordance with Article 15 of the Convention and will be based upon the principles set forth in the "Statements by the Council to Contracting States on Charges for Airports and Air Navigation Services." Cost recovery methods will not discourage the use of satellite-based safety services.

CNS/ATM is a global concept which allows flexibility in the manner and pace of implementation. Satellite technology will offer higher quality navigation and air traffic management services to be provided in all areas of the world, a principal governed by universal access, mentioned above.

A country's sovereignty is also an important consideration. In conventional ATC and air navigation technologies, line-of-sight systems dominate, and thus the civil aviation agencies of a country deal directly with the airline or user in provision of services. Under the new systems, multi-national service providers such as Inmarsat may act as intermediaries between the civil aviation authorities and the airlines, relationships which impose no threats to air sovereignty, authority, or responsibility in the control of air navigation or enforcement of safety regulations. In particular:

- A state's authority will be preserved in the coordination and control of communications.

- A state's authority will be preserved in the augmentation, as necessary, of satellite navigation services.

2.3.2.3 ICAO Annexes

The 1944 Chicago Convention foresaw the need for international agreement on many civil aviation topics, of which 12 annexes to the original convention have been adopted. These annexes concern the most important topics that today are still central to airways regulation, such as rules of the air, airways systems, and ATC practices.

The annexes spell out in detail the standards and recommended practices that are responsible for today's cooperative and integrated global civil aviation infrastructure. Their refinement and updating remain a formidable workload for the organization's Air Navigation Commission, Air Transport Committee, and Council. Over 800 amendments to the annexes have been ratified, a high percentage of these having been driven by advancing technology applications.

2.3.2.4 Regional Participation

The differences in air transport needs of the regions of the world led ICAO in 1944 to allocate ten different regions and to devise plans for developing the unique ATC and airways needs of each in a globally consistent manner.

Regional differentiation will continue, although the sands may somewhat shift as CNS/ATM modernization takes hold. Unique regional elements of air transport are driven by economic health and regional trade, geographic characteristics, and even weather patterns. These and other factors may influence characteristics of modernization for some time.

2.3.2.5 Joint ATI Financing through ICAO

Arrangements for the joint financing of air navigation facilities and services are administered by ICAO upon request from states and ANSPs, respectively. The provisions of Chapter XV of the 1944 Convention and ICAO Assembly Resolutions provide the opportunity for joint financing arrangements. The general shortage of capital for the development of facilities and the growing emphasis on cost-effectiveness provide scope for the joint financing concept to be applied by two or more states to enable them to share in the cost of implementing and operating air navigation facilities and services for international civil aviation.

In this respect, because new CNS/ATM systems have a capacity which frequently exceeds the airspace controlled by an individual state, and because of the magnitude of the investments involved, joint financing-type arrangements lend themselves well to the implementation of a number of CNS/ATM components in situations where it is, for example, very costly for a state to act alone, or where an existing regional organization (ASECNA, COCESNA, EUROCONTROL, etc.) does not act on its behalf. Such components potentially would cover all the elements of CNS/ATM, including ground-to-earth stations, communications satellite transponders, integrity monitoring, and satellite-based augmentation systems required in connection with GNSS.

Other possible applications of the joint financing concept, where facilities and costs involved are beyond the needs of a single state, include development of cross-polar routes and calibration of ground aids.

A number of prerequisites are required by ICAO for successful application of the joint financing concept:

- A clear description of the project and its objectives, which should be to facilitate (or make possible) the establishment of an air navigation facility or service, and to reduce the cost for each participant.
- A clear identification of the services to be jointly financed.
- A clear definition of the responsibilities of the different partners who would agree to participate. (In this regard, involvement of IATA as representative of the users would be useful.)
- Simplicity and flexibility of the arrangements which should be adapted to the circumstances of interested states and allow efficient implementation ("administrative agreements" to the extent possible).
- Equitable recovery of costs, including administrative costs, through user charges, as well as consistency in general with the ICAO's *Policies on Charges for Airports and Air Navigation Services* (Doc 9082).

ICAO provides support to states, when requested, to structure and implement ATI modernization. The basic activity is the development and provision of policy guidance on the economics and management of air navigation services; the development of ICAO policies on user charges; promotion and implementation of relevant ICAO policies and guidance material; and monitoring regulatory and industry developments and trends, such as conducting studies and research on related issues.

Specifically, ICAO helps deal with the economic, financial, organizational, and managerial aspects of the provision and operation of air navigation services, including issues relating to commercialization and privatization of ANSPs, relationships between providers and users, cost basis for charges, charging systems, and charges related to security and environmental protection. ICAO collects, analyzes and disseminates information on the financial situation of air navigation services. It also conducts workshops or other informal meetings to assist states and provides technical support to other bodies inside and outside ICAO on matters of its expertise areas.

2.3.2.6 ICAO Policies on User Charges

The basic policies established by ICAO in the area of airport and air navigation services charges are expressed in Article 15 of the *Convention on International Civil Aviation* (Doc 7300) which sets out the following three basic principles:

- Uniform conditions shall apply to the use of airport and air navigation facilities in a contracting state by aircraft of all other contracting states.
- The charges imposed by a contracting state for the use of such airports or air navigation facilities shall not be higher for aircraft of other contracting states than those paid by its national aircraft engaged in similar international operations.
- No charge shall be imposed by any contracting state solely for the right of transit over or entry into or exit from its territory of any aircraft of a contracting state or persons or property thereon.

While the first two of these principles do not appear to have given rise to misunderstandings, the third has in some instances been interpreted to mean that no charges are to be levied when an aircraft flies into, out of, or over a state. That, however, is not the intent of this principle since all states are fully within their rights to recover the costs of the services they provide to aircraft operators through charges.

Two other aspects are also addressed in Article 15. The first is that states shall publish all their airport and air navigation services charges, and also communicate them to ICAO. This information is collected and published by ICAO in the *Tariffs for Airports and Air Navigation Services* (Doc 7100). Article 15 also provides for ICAO, upon representation by an interested contracting state, to review charges imposed and make corrective recommendations thereon to the state concerned.

2.3.2.7 ICAO's Policies on Charges for Air Navigation Services

Additional and more detailed policy guidance is provided in ICAO's *Policies on Charges for Airports and Air Navigation Services* (Doc 9082). The contents of Doc 9082 have been revised periodically following major international conferences on airport and air navigation services economics and management, the last of which — the Conference on the Economics of Airports and Air Navigation Services (CEANS) — was held in Montreal in September 2008, with amendments published when required. However, the basic philosophy and principles expressed in the policies, fairness, and equity in the determination and allocation of airport and air navigation services costs have remained unchanged over the years.

ICAO policies on charges differ in status from the Chicago Convention in that an ICAO contracting state is not bound to adhere to the policies' provisions and recommendations, unlike the articles of the Chicago Convention. However, since the recommendations in the ICAO policies have been developed during major international conferences, there is a strong moral obligation for states to ensure that their airports and air navigation services cost recovery practices conform to the policies and philosophy set out in the ICAO policies on charges. This appears to be the general practice among ICAO's contracting states.

The policies on charges for air navigation services include the cost basis for air navigation services charges, allocation of costs of air navigation services among aeronautical users, charging systems, approach and aerodrome control charges, route air navigation services charges, and charges for air navigation services used by aircraft when not over the provider state.

Key Points:

- Emerging CNS technologies are opening new possibilities and potential for air traffic management.
- Policies put in place by ICAO must continue to control the implementation of

these technologies while adapting to new structures for funding the newly provided capabilities and services.

2.4 Other International, Regional, and National Policies and Air Law Instruments

Since it was first defined at the Chicago Convention of ICAO in 1944, the *Convention on Civil International Aviation* has been accepted by countries throughout the world and is broadly adhered to by 183 member states. The international community has also adopted a number of other legal instruments relevant to the work of ICAO. These instruments are of a bilateral or regional nature that, although not sponsored by ICAO, validate ICAO's policies.

The topic of this section is external influences whose motivation in the regulation of air transport policy stem from indirect impact of air transport upon their respective sectors.

2.4.1 National Security, Regional Security, and CNS/ATM

It is often the charter of the world's militaries to protect and maintain national borders from deliberate intrusion. Developed countries operate their airspace in close cooperation between military and civil air traffic control authorities. This enhances national security without jeopardizing the civil mission of air safety. For example, military air traffic control in peace time closely resembles civilian ATC in both equipment and procedures. Special use airspace is allocated to provide military training under real or simulated conditions that one would experience in a hostile environment.

The issue of national or regional security is of fundamental concern to the design of effective dual-use airspace and to policies and procedures that will permit the smooth and instantaneous subjugation of airspace to the military in case of a national security threat.

Satellite CNS poses some unique and challenging issues to CNS/ATM planners in this regard. While it has been determined that surveillance is accurately performed by satellite navigation augmented by ADS, it is not reasonable to assume that hostile aircraft will cooperate. Some form of radar surveillance will be required and will be present in the modernized CNS/ATM environment of the developed or developing country.

During peace time, the issue of special use airspace for training or exclusion zone purposes will also complicate matters.

2.4.1.1 NATO and Europe's Militaries

NATO and Europe's militaries face perhaps the most complicated set of requirements due to the changing circumstances facing it since the demise of the Cold War. European airspace is highly militarized. With the reorganization of NATO's mission into that of a regional or international peace keeper, and the now successful "Partners for Peace" program extending membership to Eastern European countries, Europe's airspace jurisdictional matters and missions are rapidly evolving.

The objective of NATO's civil and military ATM coordination is to support the EUROCONTROL member states to enhance the capacity, flexibility, efficiency, safety, and security of the European aviation network, while accommodating military aviation requirements. To deliver this, NATO's focus is on:

- Airspace management performance (ASM) and support systems.
- Enhancing civil-military collaborative decision-making.
- Improving civil-military CNS interoperability.
- Improving and promoting ATM security.
- Ensuring a seamless military integration in the network.
- Coordinating civil-military aspects in the SESAR program.

Non-operational considerations and civil/military needs are constantly being debated.

For example, NATO is holding informal discussions on the possibility of relocating military training flights over congested European airspace. Several Eastern European countries with less capacity constraints have offered to help, and countries in Africa and North America have also suggested NATO consider their airspace for such purposes.

NATO and European militaries contribute to ATI modernization with both technical and financial assistance. SESAR is expected to lead the way for the modernization of air traffic management system in Europe. In their capacity as airspace users, service providers and regulators, NATO and European militaries actively participate and contribute to the ongoing definition and to the implementation of the European ATM master plan.

Although the military pursue different objectives, they operate most of the time in a mixed civil-military environment, and they contribute directly (e.g. mixed airports, primary surveillance radars) or indirectly (air defense, search and rescue) to the air transport value chain.

The dynamic management of airspace, a new operational concept based on 4D trajectories or the setting up of collaborative decision-making processes across the ATM community, are among the most promising concepts under SESAR scrutiny. They all imply a high level of inter-operability of systems and procedures. As a consequence of the military requirement of access to all airspace, there will be a need to progressively bring up to standards the procedures and performance of ground and airborne military systems used for ATM purposes. The harmonization of operational air traffic rules, the promotion of common and dual purpose technologies, and the development of performance based specifications will support this paradigm shift in civil military cooperation.

2.4.1.2 DOD and the US

The FAA recognizes that the military has a continuing requirement to conduct certain training and R&D activities within airspace as free from other aircraft as practical. FAA policy on airspace falls under FAA Order 1000.1A, Policy Statement of the FAA. It is implemented in *FAA Handbook 7400.2G, Procedures for Handling Airspace Matters*, and is stated as follows:

- The navigable airspace is a limited national resource that Congress has charged the FAA to administer in the public interest as necessary to ensure the safety of aircraft and its efficient use. Although the FAA must protect the public's right of freedom of transit through the airspace, full consideration shall be given to all airspace users, to include national defense; commercial and general aviation; and space operations.

- Accordingly, while a sincere effort shall be made to negotiate equitable solutions to conflicts over the use of the airspace for non-aviation purposes, preservation of the navigable airspace for aviation shall be the primary emphasis.

DOD policy on the acquisition and utilization of special use airspace is essentially an extension of FAA policy along with additional provisions for planning, coordinating, managing and controlling those areas set aside under FAR Part 73 and other provisions for military or special use. Airspace actions within the DOD are decentralized, with each military service having its own office to set policy and oversee airspace matters. Airspace issues that require action at the DOD level are the responsibility of the DOD Policy Board on Federal Aviation (PBFA), which is composed of senior representatives of each service.

2.4.1.3 Developing Countries and Less Developed Countries

Defense programs of many countries make tangible contributions to ATI modernization in a number of ways, and the impact of military ATI investments far outweigh those of most other military expenditures in civil return measures. Increased military involvement in CNS/ATM modernization throughout the developing world will continue and likely grow. An example of countries that hold exceptional promise as fertile CNS/ATM markets for Western equipment and technologies are India, Indonesia, China, and Russia.

Key Points:

- Governments and militaries will continue to exert control over CNS/ATM sectors, but will also need to adapt their security policies to include new CNS capabilities.
- The procurement cycles for global military establishments can create significant markets for CNS/ATM suppliers.

2.4.2 Interoperability Factors: Standards, Procedures, and Certification

A primary concern of the international civil aviation community is the development of technical and operational CNS/ATM performance standards. Standards are essential to ensure interoperability of airborne and ground-based CNS/ATM equipment and to establish and maintain a common set of operating procedures to maintain flight safety. Standards also provide a baseline, or minimum requirements, that ATC and avionics equipment designers and manufacturers build to. Appropriate state aviation authorities, based on compliance with these designated standards, certify aviation equipment, systems, and procedures, for operation in their designated airspace. Certification can be either in compliance with national or international standards and also provides the basis for conformance with legal issues and regulations governing operation within a state's airspace system.

2.4.2.1 Importance of Interoperability and Need for Global Standards

International air traffic will continue to expand as modern CNS/ATM systems increasingly provide the capability for global navigation in conjunction with continued liberalization of state airspace policies and the shift to a truly global economy. International expansion requires that all aircraft must navigate using a common set of procedures and systems in order to navigate from point A to point B (seamless navigation) anywhere in the world. In order to accomplish this, modern CNS/ATM systems must be interoperable and comply with a specified set of international standards. This is especially true since the breakup of the former Soviet Union, whose aviation standards and procedures, excluding those available on international routes, did not comply with accepted international aviation standards. Since Russia, the NIS, China, and other countries which are transitioning to a free market economy represent a significant portion of potential global trade, the importance of interoperability and requirement for global standards is imperative. Below is a discussion of the most important standards-setting bodies in ATI.

2.4.2.2 RTCA

The Radio Technical Commission for Aeronautics (RTCA) was founded in 1935 and is a private, non-profit organization serving the aviation community. It provides a forum where government and industry can meet to address aviation issues and technical concepts in order to derive consensus-based resolutions and recommendations. In 1991, the organization reorganized and incorporated as RTCA, Inc.

RTCA is primarily funded by member and international associate dues. Its membership includes approximately 125 US government and business entities such as the FAA, Department of Commerce, NASA, DOD, aviation associations including the Air Line Pilots Association (ALPA), ATA, the National Business Aircraft Association, and a variety of aviation service and equipment suppliers. Approximately 30 international associates are members of RTCA. International associates include EUROCONTROL, EUROCAE, the United Kingdom Civil Aviation Authority, and Electronic Industries of Japan. RTCA's objectives include but are not limited to:

- Ensuring the safety and reliability of airborne systems.
- Developing minimum operational performance requirements for document-specific systems.

- Developing guidelines for use by a regulatory authority that the given authority determines appropriate.

- Providing administrative and logistics resources that enable teamwork among the world-wide aviation community (e.g. ICAO and the International Telecommunication Union, and others).

As a consensus-based organization, RTCA is able to significantly impact the civil aviation community. RTCA is often called upon to provide technical guidance and minimum operational performance standards for aviation navigation, communication, and surveillance. RTCA forms committees to take action on these various aviation issues and announces its meetings in the Federal Register so that they may be open to all interested parties. Parties involved in RTCA committees are volunteer authorities from government and industry who meet to discuss operation and technical ramifications of a given subject and then develop consensus recommendations.

Consensus recommendations are presented to the RTCA governing body, which will either approve the special committee report or require that additional analysis be performed by the committee. Approved recommendations are published and made available to the public for sale. RTCA recommendations are often used as a basis for business decisions. Furthermore, because RTCA serves as a federal authority committee, its recommendations often provide the basis for government policy decisions.

RTCA committees have most recently been involved with ATI are:

NextGen Advisory Committee

The NextGen Advisory Committee (NAC), established in September 2010, is a policy-level federal advisory committee tasked with developing a common understanding of NextGen priorities in the context of overall NextGen capabilities and implementation constraints, with an emphasis on the near and mid-term (through 2018). The committee provides a venue where the FAA can solicit a consensus-based set of recommendations on issues that are critical to the successful implementation of NextGen. It is also a forum to obtain a commitment of resources and/or synchronized planning between government and industry that will support and, when necessary, identify opportunities for industry participation in NextGen implementation.

In conducting its work, the committee will foster a common understanding of success with joint performance objectives and development milestones to be reviewed as implementation progresses. The committee will primarily focus on implementation issues including prioritization criteria at a national level, joint investment priorities, and location and timing of capability implementation. The committee will provide a venue for the FAA as well as industry partners to report on progress on the implementation of NextGen operational capabilities and associated airspace performance improvements.

Program Management Committee

The Program Management Committee (PMC), established December 1977, manages the technical federal advisory committee-related business of RTCA (but does not include the NAC and its subcommittees/work groups). The PMC establishes special committees in response to an identified need by government and industry. The PMC approves the terms of reference (TOR) for the special committee, approves the chairs, reviews recommendations, and reports and approves, modifies, sends back for additional work, or disapproves these recommendations and reports.

RTCA Special Committees

Several examples of important special committees are:

- **Standards of Navigation Performance:** SC-227, Standards of Navigation Performance, established December 2011, is developing navigation standards intended for designers, manufacturers, and installers of avionics equipment; airspace managers and service providers; and the users of these navigation systems for worldwide operations.

The revision to DO-283, Minimum Operational Performance Standards for Required Navigation Performance for Area Navigation, will provide guidance for the development of airspace and operational concepts needed to obtain the benefits of enhanced navigation capability in the aircraft. It will also provide the minimum set of requirements needed to demonstrate compliance with the performance and functions in the MASPS while enabling compliance with the PBN operations envisioned to support Next-Gen and SESAR. The MOPS will also be compatible with the upcoming ICAO navigation specification for advanced RNP, to be published in the update to the ICAO PBN Manual, Document 9613.

- **Standards for Air Traffic Data Communication Services:** SC-214, Standards for Air Traffic Data Communication Services, established March 2007, is developing documents in support of NextGen for services in defined environments through 2020. Data communications in support of NextGen and SESAR initiatives will introduce services that allow evolution from the current workload-intensive, voice-based air traffic control concepts, to collaborative, management-by-exception operations. Advanced datalinks between ground and airborne systems are envisioned to increase capacity allowing greater user access and more efficient flight routing.

- The committee completed DO-306, Change 1, Safety and Performance Standard for Air Traffic Datalink Services in Oceanic and Remote Airspace (Oceanic SPR Standard) in March 2011. In March 2012 it completed DO-305A, Future Air Navigation System I/A – Aeronautical Telecommunication Network Interoperability Standard (FANS 1/A – ATN B1 Interop Standard) and DO-281B, Minimum Operational Performance Standards (MOPS) for Aircraft VDL Mode 2 Physical Link and Network Layer.

2.4.2.3 EUROCAE

The European Organization for Civil Aviation Equipment (EUROCAE) is a nonprofit organization which was formed in 1963 to provide a European forum for resolving technical problems with electronic equipment for air transport. Similar to RTCA, it has special committees set up to address technical and standards issues.

EUROCAE deals exclusively with CNS/ATM aviation standardization (airborne and ground systems and equipment) and related documents as required for use in the regulation of aviation equipment and systems. EUROCAE is governed by a constitution and functions according to procedures established over 50 years of activities in the development of aviation standards.

The EUROCAE Council is made up of a minimum of eight and a maximum of 20 members elected every year by the full members at the general assembly. All council members have a high level management position in their own company or organization. The president and the secretary general (being the council secretary) are members of the council. At its first meeting (usually immediately after the general assembly), the council elects its chairman, vice-chairman, and treasurer. In addition the council establishes the schedule and place of its next meetings.

EUROCAE Council

The main role of the council is to:

- Discuss and to endorse all important operational and strategic decisions (strategic work plan, budget, partnership agreements, working processes, etc.).

- Approve the creation or re-orientation of working groups and to endorse their objectives (terms of reference or TOR).

- Decide on the publication of EUROCAE Documents (ED).

- Prepare, in collaboration with the general secretariat, the next general assembly and symposium.

- Supervise the secretary general's administration of the association.

EUROCAE council members in 2012 are:

- EUROCAE president: Jean-Paul Platzer (Airbus).

- Council chairman: Patrick Souchu (DSNA).

- Council vice-chairman: Steve Barber (UK NATS),.

- EUROCAE treasurer: Bruno Ayral (Thales Air Systems).

- As a member of right, the secretary general: Abdoulaye N'Diaye.

Industries and Organizations Members are: Airbus, AustroControl, BAE Systems, Dassault, DFS, DSNA, EASA, EUROCONTROL, GE Aviation, Indra Sistemas SA, NATS, QINETIQ, the SESAR Joint Undertaking, Thales Air Systems, and Thales Avionics.

To develop EUROCAE standards and related documents, EUROCAE organizes working groups (WGs) where members provide experts working on a voluntary basis. In general, the WG members come from the association membership, but others may be accepted under specific conditions regarding the organization they belong to and their particular expertise.

SESAR Advisory Working Groups

The most important working groups are listed below:

- **Global Navigation Satellite Services.** Chairperson: P. Ladioux (DSNA/DTI). WG-28 is tasked to update the ED-114 MOPS for the GBAS ground subsystem to support Cat I precision approach operations and optionally the GBAS Positioning Service. The MOPS is kept compatible with the ICAO Annex 10 GBAS SARPs. The testing section is updated in line with the ongoing GBAS ground equipment implementation. Furthermore, WG-28 updates the ED-88 MOPS for airborne Multi Mode Receiver for ILS and MLS to include GNSS and changes to referenced standards, given that sufficient participation is confirmed. Consideration is given to Cat II/III developments in the ICAO NSP and RTCA and to propose future EUROCAE work on GBAS CAT II/III when appropriate.

- **Automatic Dependent Surveillance-Broadcast (ADS-B).** Chairperson: Michel Procoudine (Thales Air Systems). The scope of this group is to consider the airborne and ground user needs for ADS-B and the preparation of the consequential guidance documents for its component and associated systems in accordance with ICAO and in harmonization with similar activities in RTCA.

- **Datalink Application NextGen & SESAR.** Chairperson: Danny Can Roosbroek (EUROCONTROL). The scope of this group is the development of standards to define the safety, performance, and interoperability requirements for air traffic services (ATS) supported by data communications. The group will introduce services that allow evolution from the current workload-intensive, voice-based air traffic control concepts to collaborative, management-by-exception operations; and advanced datalinks between ground and airborne systems are envisioned to increase sector-based traffic capacity, allowing greater user access and more efficient flight routing

Key Points:

- In an effort to maintain outreach, there are numerous working groups speaking on behalf of industry stakeholders.

- Working groups and other industry organizations must continue to push to improve interoperability to allow new technologies to facilitate, and not limit, policy constraints on future air traffic management.