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APEC Transportation Safety and Security Project
Satellite Navigation and Communications

Summary Report
for Study Elements 1, 2 and 3

Prepared for
Transportation Development Centre
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by
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16. Abstract

Canada is a member of the Asia-Pacific Economic Cooperation which comprises 18 economies: Australia, Brunei Darussalam, Canada, Chile, the People's Republic of China, Chinese Taipei, Hong Kong, Indonesia, Japan, the Republic of Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, the Republic of the Philippines, Singapore, Thailand and the United States. In support of APEC, Transport Canada undertook a study of the implementation of satellite navigation and communications (SN&C) for both air and marine. The study consists of the following elements:

- Element 1 - Inventory of Existing and Planned SN&C Systems in APEC economies;
- Element 2 - SN&C Technology and Safety Review; and
- Element 3 - Costs and Benefits of SN&C for Air and Marine Transportation.

This report summarizes the reports prepared for the three elements, and in particular covers:

- A trade and traffic (marine and aviation) analysis of the 18 economies along with a review of their implementation plans for SN&C technologies.
- A broad introduction to the satellite-based technologies which make navigation and communication possible in the air and marine environments.
- The results of Expert Panels on the safety issues arising from the use of the SN&C technologies.
- A methodology that identifies and quantifies the potential benefits and costs of implementing the SN&C technologies in the aviation and marine sectors for any APEC economy or group of APEC economies.

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List of Related APEC Transportation Safety & Security Project Reports

TP 12928 APEC Transportation Safety & Security Project
Satellite Navigation and Communications
Summary Report for Study Elements 1, 2 and 3

TP 12929E APEC Transportation Safety & Security Project
Satellite Navigation and Communications
Element 1 - Inventory of Existing and Planned SN&C Systems in the APEC Economies
Part 1: Trade, Traffic and APEC

TP 12930E APEC Transportation Safety & Security Project
Satellite Navigation and Communications
Element 1 - Inventory of Existing and Planned SN&C Systems in the APEC Economies
Part 2: Implementation Plans

TP 12931E APEC Transportation Safety & Security Project
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Element 2 - SN&C Technology and Safety Review in the APEC Economies
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TP 12932E APEC Transportation Safety & Security Project
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TP 12933E APEC Transportation Safety & Security Project
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Element 3 - SN&C Costs and Benefits Assessment in the APEC Economies

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1. Introduction

1.1 APEC Satellite Navigation and Communications Study

The Asia-Pacific Economic Cooperation (APEC) comprises 18 economies: Australia, Brunei Darussalam, Canada, Chile, the People's Republic of China, Chinese Taipei, Hong Kong, Indonesia, Japan, the Republic of Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, the Republic of the Philippines, Singapore, Thailand, and the United States. These economies have agreed to cooperate in four areas: global and regional economic development, global trade liberalization, and regional cooperation in specific sectors. One of the sectors identified is transportation. The Transportation Working Group (TPT/WG) was created to coordinate that effort.

The ambitious agenda for liberalizing trade in the region will bring about a rapid increase in air and marine traffic and a requirement for higher levels of aircraft and shipping throughput. This demand for increased capacity is driving the application of satellite communications, navigation and surveillance technologies and systems. It is apparent from discussions in the TPT/WG that the economies of APEC share an interest in introducing new technologies and systems in a way that maintains or improves transportation safety.

The Canadian Minister of Transport has made a commitment to APEC Ministers of Transportation to lead the promotion of transport system safety in the APEC region. To that end, Transport Canada proposed a study on the implementation of satellite navigation and communications (SN&C) for both air and marine. The study is a component of the APEC Action Program in Transportation.

The study is composed of the following elements:

- Element 1 - Inventory of Existing and Planned Satellite Navigation and Communications Systems in the APEC Economies;

- Element 2 - Satellite Navigation and Communication Technology and Safety Review; and

- Element 3 - Costs and Benefits of Satellite Navigation and Communications for Air and Marine Transportation.

Hickling Corporation was contracted to carry out the work for the three elements and detailed reports have been prepared. This report presents a summary of those detailed reports.

1.2 Report Structure

This summary report is structured as follows.

Section 2 Inventory of SN&C Systems
The Inventory of Existing and Planned SN&C Systems Report (Element 1) presents the results of a trade and traffic analysis and of a review of aviation and marine SN&C implementation plans for the APEC economies. Section 2 presents a summary of the Inventory Report; the information is introduced under two main headings, Trade and Traffic, and Implementation Plans.

Section 3 Technology Review
The Technology Review Report (Element 2) provides a broad introduction to the technologies which make navigation and communication possible in the air and marine environments. The emphasis is on navigation; communications are included to the extent that it supports navigation, surveillance and management of air and marine traffic. Section 3 presents a summary of the satellite-based technologies for navigation, communication and surveillance in the aviation and marine transportation sectors.

Section 4 Safety Review
Also under Element 2 of the study, two reports were produced: i) Expert Panel on Safety Issues - Air Transportation; and ii) Expert Panel on Safety Issues - Marine Transportation. The reports record the results of the two Expert Panels concerning issues arising from the use of SN&C technologies. The Panels were held in support of the international effort by APEC economies to accommodate increasing traffic in a safe manner. Section 4 summarizes the two reports by describing the process used for the expert panels and presenting the findings.

Section 5 Costs and Benefits Assessment
The Costs and Benefits of Satellite Navigation and Communications for Air and Marine Transportation Report (Element 3) describes a methodology that identifies and quantifies the potential benefits and costs of implementing SN&C technologies within the aviation and marine sectors for any APEC economy or group of APEC economies. Section 5 presents a

summary of the Benefits and Costs of SN&C Report. An overview of the methodology is provided, the illustrative examples are described, and the impacts presented.

A list of acronyms appears in the Appendix.

1.3 SN&C as Compared to CNS/ATM

As described above, the focus of the APEC SN&C Study is the implementation of satellite-based communication and navigation systems or SN&C in the APEC region. There are a number of technologies which fall under this heading such as the Global Positioning System and satellite data link. The International Civil Aviation Organization has developed a global plan to transition to satellite-based communications, navigation **and** surveillance (CNS) including the required air traffic management capabilities (ATM). In aviation these satellite-based technologies have come to be referred to as the new CNS/ATM systems. In this report, the SN&C acronym has been used exclusively for the marine sector; for the aviation sector, the SN&C term is used where possible but in many instances the CNS/ATM term is more appropriate.

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2. Inventory of SN&C Systems

2.1 Introduction

The Inventory of Existing and Planned SN&C Systems Report (Element 1) presents the results of a trade and traffic analysis and of a review of aviation and marine SN&C implementation plans for the APEC economies. In particular the report provides an overview of the key traffic patterns and supporting infrastructure development resulting from the growing trade in the region. In response to the increasing demand on marine and aviation transportation, the economies are increasing capacity through different means including the implementation of SN&C technologies. The Inventory Report also provides a general overview of the economies' implementation plans.

This section presents a summary of the Inventory Report. The information is introduced under two main headings: Trade and Traffic, and Implementation Plans.

2.2 Trade and Traffic

At present the Asia-Pacific region boasts the highest level of economic growth in the world. It is transforming itself from the "world's factory", exporting inexpensive industrial products, to a "vast consumer market" in its own right. APEC's principal role is to create an environment conducive to the sustained growth of the Asian economy, dubbed the world's growth centre. Many of the countries within this region are currently experiencing Gross Domestic Product (GDP) growth rates exceeding 6.0 percent; the GDP will be higher in Asia-Pacific than in North America by 2010. APEC economies currently have 38.9 percent of the world's population and produce 51.6 percent of its total GDP. High growth trends and increased per capita income have placed a great strain on transportation infrastructure, both air and marine.

2.2.1 Air Transport

Recent increases in Asia-Pacific international passenger growth reflect strong economic growth in the region as a whole. Passengers have the wherewithal to buy tickets, and real income expansion is fuelled by cargo traffic (export trade) and purchase requirements (import trade). The unique geography of the region has continued to fuel growth as many of the countries are islands, making air travel the primary mode of transport. In addition, political stability, relaxation of travel restrictions (primarily Korea and Taiwan) and increased personal disposable income have contributed to the overall growth in air travel.

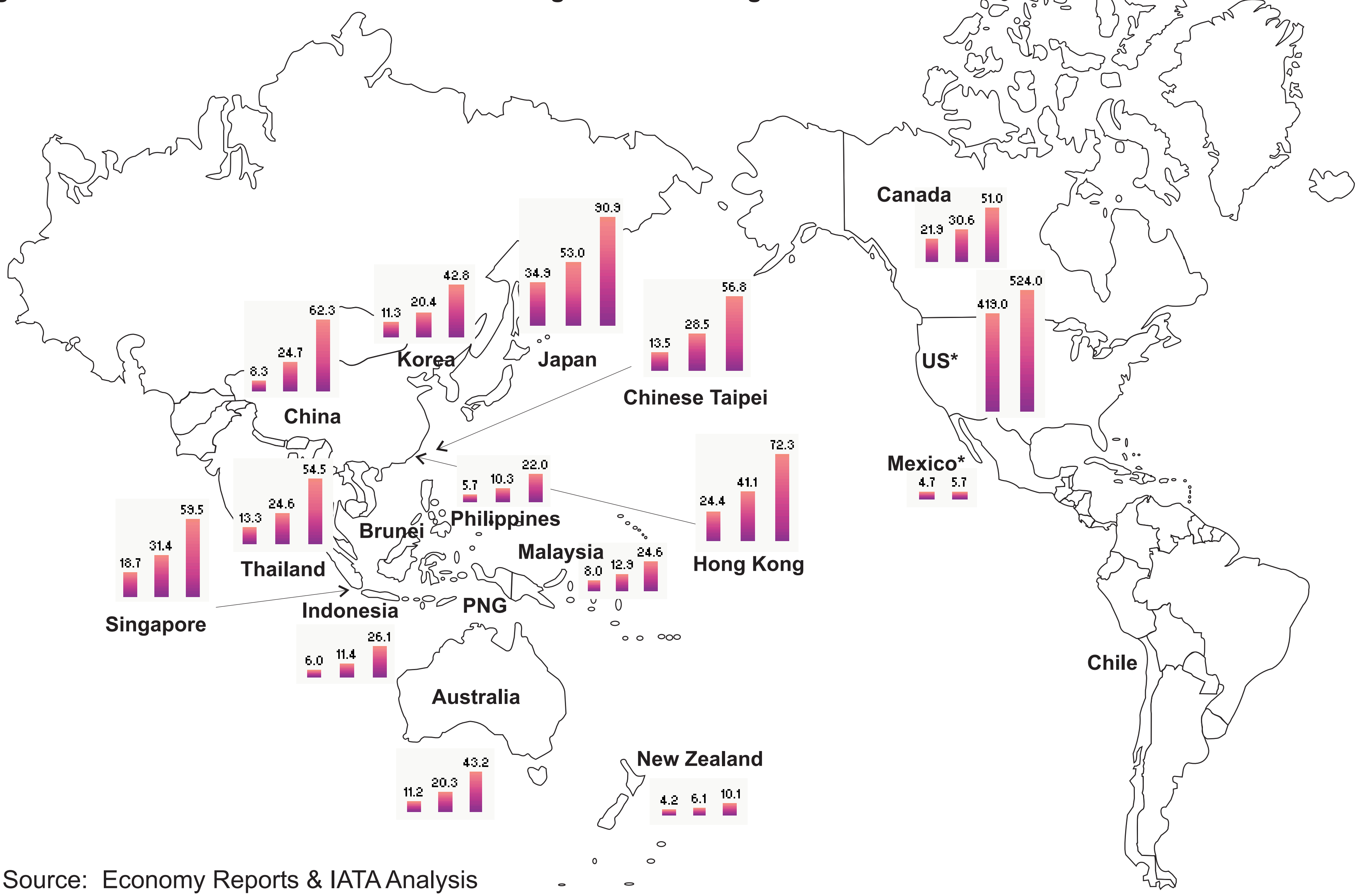
Demand for air transport (typically driven by passenger demand) in the Asia-Pacific region is now growing faster than in any other world region. By 2010, Asia-Pacific will have more international scheduled passengers than the rest of the world, exceeding 50 percent of the world total. Between 1993 and 2000, Asia-Pacific international scheduled passenger traffic will grow by 8.6 percent per annum reaching a new peak of 200 million passengers in 2000. By 2010 this figure will increase to 398 million; 3.5 times higher than in 1993. In comparison, the rest of the world will reach an aggregated 390 million passengers by 2010. Consequently, the global share of Asia-Pacific international passenger traffic will have increased from 26.4 percent in 1985 to 35.3 percent in 1993, and will increase even further to 50.5 percent by the year 2010. Figure 2-1 presents historical and forecast international passenger traffic for economies in the region.

Increased traffic in the APEC region is expected to reflect and follow current trends. That is, scheduled traffic on *long-haul routes* (routes greater than 1500 nm in length) has been and will continue to remain *dominant*. Not only is long-haul route growth expected to continue, but average travel distances along long-haul routes are expected to increase. Short-haul routes, on the other hand, will achieve lower rates of growth than any other routes. Figure 2-2 presents 1994 growth in main inter-regional air traffic flows.

In terms of region pairs, the most dominant pairs are and will remain within the Asia-Pacific area. By 2010 five Origin-Destination pairs in this region will be showing air traffic exceeding 10 million passengers annually: China-Hong Kong, Japan-U.S. Mainland, China-Taiwan, Japan-Korea and Hong Kong-Taiwan.

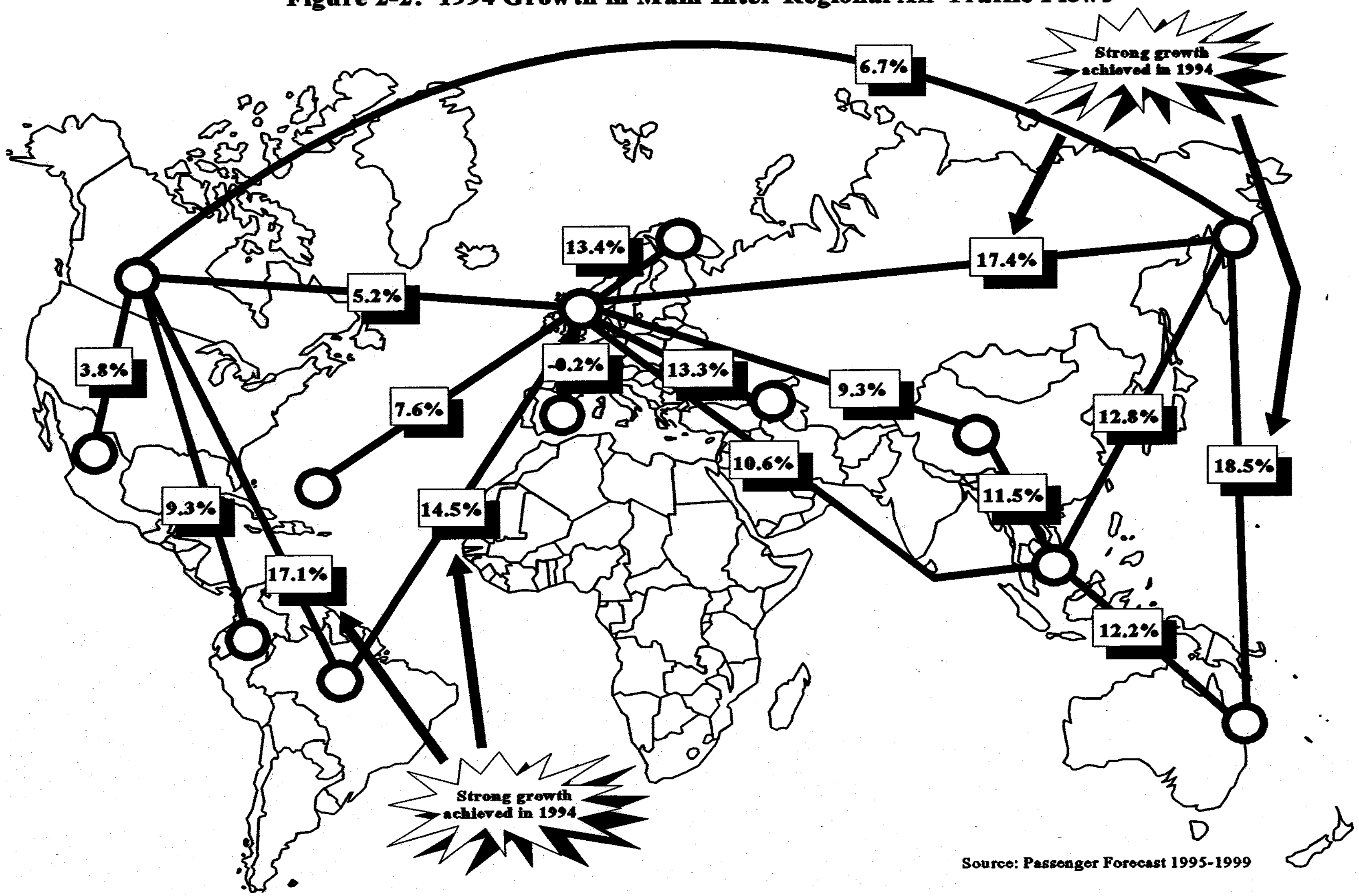
To cope, economies of the region are investing heavily in new airports. Five new airports have opened since 1980 - Singapore/Changi, Jakarta/Sukarno Hatta, Osaka/Kansai, Macau and Shenzen, China. In contrast, the U.S. opened only one major international airport in the past 25 years, Denver International Airport, and no airports are under construction. While in the Asia-Pacific region, six more are under construction or planned to be in operation by 2005 - Kuala Lumpur Airport in Malaysia, New Seoul Metropolitan Airport and Chengju, South Korea's two new airports; New Bangkok International Airport in Thailand; Changhai Airport at Pudong, China, and Hong Kong's Chek Lap Kok Airport. By constructing these airports, Asia is preparing the foundation for future economic development.

Figure 2-1: The Scale of International Air Passenger Traffic Among APEC Members



Source: Economy Reports & IATA Analysis
Notes: Passenger traffic in millions for 1993, 2000 and 2010
* Data for these countries are for 1993 and 1999 only

Figure 2-2: 1994 Growth in Main Inter-Regional Air Traffic Flows



Source: Passenger Forecast 1995-1999

However, airspace capacity in Asia has been falling behind airport development. Air traffic control systems and procedures in the past have not kept pace with traffic growth. With new airports designed to handle millions of passengers, the primary obstacle to this growth is airspace congestion. The key to removing this obstacle is the implementation of CNS/ATM hardware and the procedures necessary to gain the efficiency and reduced separation needed to accommodate the air traffic growth. As a result, the APEC economies are jumping in to lead the world in the use of satellite navigation and communication for air traffic management.

2.2.2 Marine Transport

The more industrialized economies of the region have succeeded in moving into the production of export items by incorporating high domestic value-added and technological sophistication, and then market diversification. These economies have not only developed inter-regional exports but have also become increasingly important markets for each other's exports. To serve these supply capabilities and external demand for manufactured exports, there has been a rapidly expanding requirement for seaborne traffic. Energy must be shipped in tankers and liquid natural gas (LNG) vessels. Ores must be carried in bulk carriers, as must timber, grains, oilseeds and other commodities. But more importantly, consumer and capital goods need containers and the specialized vessels or cargo ship deck space to carry them. These marine cargo requirements have put great pressure on port capacities and the infrastructure that supports them. Passenger demand does not typically have a significant effect on marine traffic levels.

Total inter-regional seaborne general cargo trade comprising break-bulk and unitized cargoes is estimated to have reached 50 million t in 1993. About 45 percent of the total cargo from Taiwan, China and from Korea is destined for Hong Kong, a considerable portion which is expected to go to China. The exports of Taiwan, are 1.4 times larger than its imports and the Korean exports are almost three times the volume of imports.

Hong Kong and Singapore were ranked as the world's first and second largest ports in container volume in 1993, handling over 9 million TEUs (or 20-foot equivalent units), twice as many as in 1989. Both ports are pouring money into expansion; Hong Kong alone plans to be able to handle 32 million TEUs by 2011. The combined throughput of these two ports alone accounts for 16.7 percent of the world total volume. This large portion reflects both ports' transhipment activities linking feeder services with trunk lines.

The most active ocean route is China to/from Japan; this route is serviced by over 2 000 vessels a year, undertaking over 8 000 voyages in each direction (i.e., 16 000 plus in total). The next most heavily travelled route is Japan to/from Southeast Asia, where there are about 5 000 voyages, in each direction (9 200 in total), using 1 800 vessels a year. The next largest group of voyages are Japan to/from Australia and New Zealand, with about 3 500 voyages in each direction (7 000 in total) using 1 200-1 400 vessels each year. Southeast Asia to/from Australia and New Zealand also has intensive traffic, registering some 2 000 voyages in each direction (4 000 in total), employing some 1 000 vessels. There is also significant marine trade between China and Australia and New Zealand C 1 200 voyages (2 500 in total) and around 600 vessels.

Trans-Pacific marine trade is dominated by the Japan to/from U.S. Southwest and U.S. Northwest traffic. On the U.S. Southwest route around 2 000 voyages in each direction (4 100 in total) are undertaken by around 800 vessels. On the U.S. Northwest route, the indicators are 1 800 voyages (3 700 in total), and 700 vessels. For Western Canada, the Japan route is the most important with about 1 300 voyages (2 650 in total), using some 600 vessels.

Los Angeles and Long Beach ports are the two largest in the U.S. and they expect to **double** cargo volume by 2020. Independently, the ports of Long Beach and Los Angeles are the two largest in the nation. Combined, they *rank third in the world* for container trade. The Port of Long Beach is the number one container port in the United States. Nearly 80 percent of all international cargo crossing Long Beach is moving to or from Asia, with Japan, China, Hong Kong, South Korea and Taiwan being the leading top five trade partners.

Vancouver is Canada's largest port, and consistently in the top five North American ports in terms of foreign import and export tonnage. It is the largest bulk port on the North American west coast with tonnage throughput in 1995 exceeding 71.5 million t. The Port of Vancouver currently has two container terminals; to meet the growth in container volumes projected over the next decade, the Port of Vancouver is planning an additional container facility, *Deltaport*, which will double the Port of Vancouver's overall container capacity to more than one million TEUs per year.

Recent strong growth of in-bound TEU (manufactured imports) traffic to the West Coast is resulting in mounting sea-lane and port congestion. Both Long Beach and Los Angeles see their TEU traffic doubling by 2020. For traffic originating from China, Hong Kong, South Korea, and Latin America, the doubling could occur before 2010.

2.3 Implementation Plans

2.3.1 Data Collection

Process

Data was collected on the following five aspects of satellite navigation and communication for marine and air transportation in the APEC region: trade and traffic patterns, implementation plans and issues, SN&C technologies, safety, and economics. A three-stage approach to data collection was developed: i) *Documentation Review* - A thorough literature search was conducted to identify, compile and review documented information of SN&C technologies, systems, implementation plans and issues; ii) *Data Collection Instruments* - This stage involved the design of a consultation guide and accompanying data collection forms; iii) *Consultations* - Consultations were conducted with economy representatives to the APEC TPT/WG and other international organizations.

Results

Contacts were made with the APEC TPT/WG members from all 18 of the economies as well as representatives of civil aviation and marine authorities. Responses to the consultation guide and the applicability of supplemental information provided have been varied. All told, 15 of the 18 economies responded for their aviation sector by either filling out the questionnaire and/or sending documentation; nine responded for marine. Data were then collected from other sources such as articles, home pages on the Internet and second-party documents to provide information for all but one economy in the aviation sector and five in the marine sector. Table 2-1 presents a summary of the data collected from each of the economies.

As can be seen from Table 2-1, complete data (i.e., detailed implementation plans, responses to the consultation guide, supporting documentation) for the aviation sector were collected from eleven of the eighteen economies, for the marine sector from eight economies. Basic data (i.e., less detailed implementation plans, no or sketchy response to consultation guide, minimal documentation) have been collected for aviation from four economies; and marine, three economies. Finally, minimal data (i.e., no implementation plan, no or limited response to consultation guide, little or outdated supporting documentation) have been collected from two economies for aviation and two for marine. Economy reports were prepared and submitted to each economy for their review and comment.

Table 2-1: Summary of Data Collection Results by Economy

Economy	Sources of Marine Information			Sources of Aviation Information			Data Completeness		Economy Report Comments Received	
	Interview	Guide	Docmn't	Interview	Guide	Docmn't	Marine	Aviation	Marine	Aviation
Australia	✔		✔	✔		✔	●	●	✔	✔
Brunei	No data was available				✔		None	▲		
Canada	✔		✔			✔	●	●	✔	✔
Chile	No data was available				✔		None	▲		✔
China			✔			✔	■	■		
Chinese Taipei		✔			✔		●	●		
Hong Kong			✔		✔	✔	▲	●		
Indonesia	No data was available					✔	None	■		
Japan			✔			✔	▲	▲	✔	✔
Korea	No data was available				✔		None	●		✔
Malaysia		✔			✔		●	●		
Mexico			✔		✔	✔	■	●		✔
New Zealand	✔		✔	✔	✔	✔	▲	●		
PNG	No data was available									
Philippines	✔		✔		✔		●	●	✔	✔
Singapore	✔				✔	✔	●	●	✔	✔
Thailand	✔				✔	✔	●	▲	✔	✔
United States	✔		✔	✔		✔	●	●		

● Completed Data **▲ Basic Data** **■ Minimal Data**

2.3.2 Implementation Plans

It is important to note that the following information on implementation plans is based on information that was collected from the economies and other sources between March and September of 1996. Given the rapid implementation of CNS/ATM in the region, this information may become outdated quickly. Also, implementation dates are based on the economies having initial operational capabilities and these may be available only on certain routes or in limited portions of an economy's airspace.

Summary of Economies' Aviation Plans
Nowhere in the world is the transition to CNS/ATM being accomplished more rapidly than the Asia-Pacific Region. Not only have most of the economies developed their implementation plans for the transition to CNS/ATM, but many of them already have some elements of the CNS/ATM system operational. The following information describes the region's accomplishments and its future plans for implementing the key components of CNS/ATM.

Controller Pilot Data Link Capability (CPDLC)
The CPDLC provides direct satellite/aircraft links allowing data between the pilot and the controller. CPDLC is an integral component of CNS/ATM implementation. The economies are well on the way to having CPDLC available in the region. Australia, New Zealand, Singapore and the United States have satellite data link communications (based on the ARINC 622 communications). China and Thailand will have initial operations of CPDLC in 1996 with Japan, Korea and Malaysia following suit in 1997.

Automatic Dependent Surveillance (ADS)
Satellite-based surveillance systems are not only being planned in the region but also implemented. In the South Pacific, current implementation of CNS/ATM systems is focussing on ADS. Today, ADS is operational in the oceanic airspaces of New Zealand, Australia, Singapore and the United States; in the next two years it will become operational in China, Hong Kong, Japan and Thailand.

It is important to note that the ADS data link is accomplished via INMARSAT II Pacific Ocean Region Satellite and is implemented based on the ARINC 622 specification (known as FANS-1) and does not meet the requirements of the ATN. In order to obtain the major benefits associated with flexible routing and reduced separations as early as possible, it was decided to implement a system based on the ARINC 622 standard instead of waiting for the ATN Standards and Recommended Practices (SARPS) which are currently under development. As a result, economies that have implemented early (i.e., Australia, New Zealand, Singapore, etc.) will have an ADS system based on FANS-1 architecture while economies that wait for the ATN SARPS (e.g., Canada) will have a different architecture. This could create difficulties in implementing seamless operations.

Global Navigation Satellite System (GNSS)
Progress has also been made on the implementation of GNSS. Currently, GPS en route has been approved for use in Australia, Canada, New Zealand and United States; approval is scheduled for Japan and Singapore in 1997. Significant work has also begun on the development of GPS overlays for non-precision approaches in Australia, Canada, Singapore and the United States.

The region is also evaluating the potential for a Regional Augmentation System (RAS). Japan is currently developing its Multi-Functional Transport Satellite (MTSAT) which will be the backbone of the air-ground data/voice communication system. This system will provide a means for ADS and GNSS augmentation in the region. The current schedule indicates that the system will have initial operational capability in 1999.

Australia is actively investigating the implementation of a wide area augmentation system. The economy has awarded a contract to undertake a GNSS augmentation systems audit and cost benefit analysis. Australia has also joined forces with New Zealand and the United States to develop an Augmentation Systems Test Bed (ASTB) in Australia during 1996/97. The aim of the ASTB is "to improve the integrity of GPS and GLONASS systems to support sole-means en-route, non-precision approach and, where the appropriate, differential corrections are provided, Category 1 precision approach requirements."

Aeronautical Telecommunications Network (ATN)
The ATN will provide for the interchange of digital data between a wide variety of end system applications supporting end users. Implementation of the ATN will allow for a seamless and global interchange of aeronautical information worldwide. It is an integral component of CNS/ATM and each economy needs to plan for its implementation. Only, Australia, Canada, Chile, New Zealand, Singapore and the United States have set specific dates for their transition to the ATN. New applications are being defined so that the transition from ARINC 622 to ATN data exchange will require minimum redesign of existing applications. However, it is important that all economies include a transition timescale to the ATN in their implementation plans.

Summary of Economies' Marine Plans
As with the aviation implementation plans, the marine plans are based on information collected over a six month period in 1996. As such, the information may not always represent the current state of implementation of SN&C technologies in the marine sector. Also, the information was based on data from only ten economies and may not provide a complete picture of SN&C implementation in the region.

Global Positioning System (GPS)/Global Navigation Satellite System (GLONASS)
Unlike aviation, there is less criticality to the signal availability, reliability and integrity of GPS/GLONASS for marine navigation. As a result, marine users have been able to incorporate the use of GPS for navigation without the immediate need of augmentation systems. This technology is available across the Asia-Pacific region and is used primarily by large commercial ships and other classes of vessels in ocean/offshore areas, where navigational hazards are not a significant factor, and accuracies of basic GPS/GLONASS are acceptable. It is also increasingly being used by smaller vessels, including recreational vessels, particularly in coastal and inland waterways, due to falling prices for receivers.

Differential GPS (DGPS)
In the marine mode, DGPS is mainly used by large commercial ships in confined waterways, including ports, harbours, and harbour approaches. Other users include specialized marine activities including exploration and hydrographic services. Publicly provided DGPS is currently available in many areas of the United States, notably the coastal areas and in major inland waterways. In Canada, publicly-provided DGPS was made available in the summer of 1996 in coastal areas and in the Great Lakes/St. Lawrence waterway. Australia, China, Hong Kong and Singapore have implemented the beginnings of their DGPS networks.

Electronic Navigation Chart (ENC)/Electronic Chart Display Information System (ECDIS)
For some time now, commercial firms have realized the value and desirability of electronic charts that could be developed fairly simply from paper charts. As a result, there is a proliferation of "electronic charts" supplied by the private sector. However, the fact that commercially-developed data do not originate from a government authorized Hydrographic Office (HO) means that the charts do not comply with the International Maritime Organization (IMO) Performance Standards or the International Hydrographic Organization (IHO) data standard (S-57), and, therefore, cannot be used as a substitute for paper charts. Private-public consortia (e.g., such as that established in Canada) may lead to a faster overall delivery of S-57 data in the future. In the meantime, Canada, Japan, Singapore and the United States are the only APEC economies to have progressed significantly in the development of ENC data, although Australia and Hong Kong are committed to near-term development.

The real value of ECDIS is in the ability to combine digitized charts with real-time navigational positioning such as that offered by GPS/DGPS. Major benefits may also be realized in the more frequent update of chart data. With respect to updates of the ECDIS data in the future, satellite communication (e.g., INMARSAT) is perceived as a highly effective approach for the update and dissemination of data, including the update of data between providers/distributors of chart data and users. Based on the information collected, economies such as Canada and Japan put ECDIS to practical use with the IHO and IMO standards. Australia and the United States have been conducting operational trials of the system while Hong Kong is beginning their program to support ECDIS.

The IHO is responsible for the development of electronic chart standards that would complement the performance standards developed in cooperation with IMO and form the basis for the ECDIS system. A final (third) draft edition of the standards was announced in October, 1996. The IHO, through its Worldwide ENC Database (WEND) system has planned for ENCs to be developed on a regional basis through Regional ENC Coordinating Centres (RENCs). At present, the Northern European RENC, based in Norway, is the only one to be established and planning operational trials in late 1997. For the concept of RENCs to work, it is necessary for the RENCs to establish bilateral agreements with the individual HOs within the region, covering conditions for availability of data, and reimbursement for use.

The Japanese Hydrographic Department has agreed to set up a RENC for East Asia and is discussing the formation with neighbouring countries.

Satellite Communication (SATCOM)
The principle marine satellite communication system in use today is INMARSAT which as of 1995 provided marine communications to approximately 30 000 (or 25 percent) commercial or government ships around the world from four satellites placed to cover all the major oceans and seas. The number is growing dramatically and is expected to reach approximately 90 000 as early as 1997.

Currently, the Global Maritime Distress and Safety System (GMDSS) is a major element in the continuing implementation of satellite-based marine communications systems. In 1971, IMO identified requirements and began development of GMDSS. Information from APEC consultations indicate that Rescue Coordination Centres (RCCs) have been established in Australia, Canada, the United States, Japan, Hong Kong and are being implemented in Singapore and Thailand. The Philippines will begin implementation within the next year. The implementation of GMDSS is of primary importance to economies that have not yet done so as the Safety of Life at Sea (SOLAS) convention requires implementation by 1999. As a result, GMDSS will be the focus of a number of economies over the next two years.

In addition to the medium, high and very high frequency radio systems, the majority of economies (for which data was available) have satellite communication capabilities. These services are provided by one or more of the many INMARSAT systems available for maritime use. Of the economies for which data was available, only the Philippines and Thailand do not currently have satellite communications but both economies are planning for these communications as part of their GMDSS programs.

2.3.3 Summary of Implementation Levels

Table 2-2 presents the levels of SN&C implementation that were assigned to each of the economies. A level of either high, medium or low (in some instances a level such as medium to high was assigned) was based on an assessment of the information collected using the following criteria:

Table 2-2: Summary of SN&C Implementation Levels

Economy	**Level of SN&C Implementation**	
	Marine	**Aviation**
Australia	Medium High	High
Brunei Darussalam	na	Low Medium
Canada	High	High
Chile	na	Medium
China	Medium	High
Chinese Taipei	Low	Low
Hong Kong	Medium High	Medium High
Indonesia	na	Medium
Japan	na	High
Republic of Korea	na	Medium High
Malaysia	Medium	na
Mexico	na	Medium High
New Zealand	Low	High
Papua New Guinea	na	na
Republic of the Philippines	Low	Low
Singapore	Medium	High
Thailand	Low	High
United States	High	High

na - Data not available to support assessment of level of implementation

- Implementation of SN&C technologies to date;
- Involvement in development work and operational trials;
- Degree to which the SN&C technologies are to be implemented in the economy; and
- Schedule for implementation of the SN&C technologies.

2.3.4 Implementation Issues

As the Asia-Pacific region progresses toward satellite-based technologies, many concerns and issues regarding implementation have arisen which may potentially affect the timing and magnitude of the benefits and costs of SN&C implementation. Concerted efforts are being undertaken by ICAO and IMO to identify and address these issues. However, there may also be actions which APEC can take that will assist these international organizations in resolving these implementation and transition issues.

Sovereignty and Political Will

This is a critical issue for aviation but a lesser one for marine. The initial implementation of CNS/ATM has focussed attention on sovereignty issues. These include: the potential threat to revenues, jobs, and airspace and system "control"; and the need to find formulae for the sharing of facilities that safeguard the basic concerns of all economies. These sovereignty concerns differ according to economy and a regionally-based approach to overcome them is required. There is a need to establish the optimum number and location of facilities whether for satellite systems, reference and master stations or Air Traffic Control (ATC) services for the APEC region. From a marine perspective, the duplication of RENCs may also be affected by sovereignty concerns.

National Security

With the move towards services such as navigation and satellite communications being provided by third parties, be they private or public, some economies fear that the level of authority and control over their airspace may be diminished.

Harmonization of Capabilities and Implementation Timing

To achieve the full impact of SN&C technologies, it is critical that APEC economies harmonize the capabilities of their systems, the implementation timing and the application of standards and regulations to provide a seamless operating environment to the users.

Duplication of Equipment and Services

Whilst encouraging economies to consult with each other in harmonizing implementation of SN&C systems, it is also important, through advice and guidance, to persuade economies to collaborate in the provision of systems and services to avoid duplication.

Coordination and Planning

In order to achieve the full benefits of the SN&C technologies, it is important that economies liaise with their neighbours and coordinate their implementation plans. Implementation plans need to be developed by all of the economies in the region to achieve harmonization of equipment and services, safety, efficiencies and cost-savings through compatibility between systems and avoidance of duplication.

Availability and Application of Standards/Regulations
The unavailability of standards/specifications may result in: the delay of SN&C implementation; the use of non-standard equipment or procedures; or the need to carry multiple types of equipment to accomplish similar navigation and communication tasks in different areas of the region or in different regions. These may have possible safety, duplication, and cost implications, especially if the equipment is not upgradable to the approved standard.

Technical Assistance
Many economies have expressed an essential need for external technical support, and their preference for such support to be provided through the International Civil Aviation Organization (ICAO). Technical assistance is required in a wide variety of areas including but not limited to: data link communications, ATN, ADS, ECDIS, airspace reorganization, ENC development, certification, human factors and benefit-cost analysis. In some instances not only a transfer of knowledge may be desired, but personnel may be needed as many economies are occupied with upgrading the current terrestrial systems.

Costs/Funding Requirements
The implementation of SN&C technology will require significant investments in a number of areas including system development, procurement and installation of equipment, operations and maintenance and related transition costs such as training, work force adjustment, decommissioning and procedures development. Availability of funding is an issue for both the users and the economies, and is closely related to the costs of the implementation of SN&C and its ongoing operations.

Training
Economies have placed great emphasis on the importance of the identification of human resource, management and training requirements. This is especially the case with the introduction of the extremely complex SN&C technologies in avionics, ship bridges and control/monitoring stations. Assistance will be required for both the provision and financing of these activities.

User Acceptance
Many of the benefits of implementation will be governed by the acceptance of the technology by the transportation system users. The benefits to users that have promulgated the necessary SN&C investments are dependent on the proportion of users that have yet to adopt the technology. As a result, the full potential may not be achievable until a certain threshold proportion of users are appropriately equipped.

2.3.5 Potential APEC Actions

Encourage Support
The APEC TPT/WG brings together ministerial, governmental and technical individuals in a single forum. It is important that political support be given to the organizations involved for, without political support, there will be limited commitment to SN&C. This forum could be used to stress the importance of providing support to individual economies as well as planning and implementation initiatives in the APEC region.

Coordination/Planning
Given the importance of coordination and planning to the implementation of SN&C technologies, another regional forum that could be used to assist with these activities may be beneficial. Regional implementation plans such as the Asia-Pacific Air Navigation Planning and Implementation Regional Group (APANPIRG) plan could be reviewed to ensure that the economies are progressing as per the schedule.

Standards/Regulations
APEC could possibly support ICAO and IMO in their roles as developers of standards and/or regulations. In particular, APEC could provide support for the implementation of ICAO, IMO and industry standards throughout the region.

Technical, Funding and Training Assistance
There are three primary areas where APEC may be able to provide assistance to the SN&C implementation efforts:

- Technical - provide a forum for the dissemination of technical data and information;
- Funding - provide venues, funding and/or assist with funding arrangements for a variety of activities such as planning, education and training, WGS-84 implementation, etc.
- Training - provide assistance to international and regional organizations for training programs.

Information Exchange
APEC could provide a venue for the exchange of many kinds of data including technical data, implementation plans and schedules for both Asia-Pacific as well as other economies, and training programs and facilities.

2.3.6 Conclusions

Aviation Conclusions

- Based on the information collected, the following conclusions were made regarding SN&C systems in the areas of implementation plans, issues and potential APEC actions.

Implementation Plans

- By the year 2005, all member economies (for which information was available) will have either initiated implementation of or achieved operational use of the CNS/ATM systems that they will be implementing.
- By the year 2005, wide area augmentation will be available throughout most of the region via systems such as Japan's MTSAT and the United States' WAAS.
- By the year 2000, CPDLC and ADS (FANS-1) will be available throughout most of the oceanic airspace providing users with the significant benefits associated with flexible routing and reduced separations.
- Not all member economies have identified their plans for transition to ATN as well as ADS-ATN; it is important that economies do so to ensure that coordination between the providers and the users is maintained resulting in an effective, efficient and beneficial transition for economies and users alike.
- The region has moved into the implementation and operational phase of CNS/ATM.

SN&C Implementation Issues

- Given the high level of response to this question, the identified key issues will likely be representative of the opinions of the member economies.
- The implementation issues that were of key concern to the economies who responded to the questionnaire were: Harmonization and Seamlessness (6 out 13 thirteen responses); Standards and Regulations (5/13); Cost and Funding (5/13); Training (5/13); User Acceptance (5/13); and Coordination and Planning (4/13).

APEC Actions

- Given the high level of response to this question, the identified key APEC actions will likely be representative of the opinions of the member economies.
- The key potential APEC actions that were identified by the member economies were: funding assistance particularly in the area of training (8/10); information exchange (7/10); coordination and planning (6/10); and encouragement and support (4/10).
- Member economies did not indicate that APEC actions should focus on resolving the issue of availability of standards and regulations.

Marine Conclusions

Based on the information collected, the following conclusions have been made regarding SN&C technologies in the areas of implementation plans, implementation issues and potential APEC actions. It is important to note that the following conclusions are based on data from only ten economies; and therefore, may not represent a complete picture of SN&C implementation plans in the region.

Implementation Plans

- Implementation of DGPS is progressing in the region as two economies have fully operational networks of DGPS and implementation is underway in four other economies.
- Implementation of ECDIS is progressing slowly with only four economies currently using the technology; one other economy is beginning their program to support ECDIS.
- Availability of IHO S-57 ENCs for the region may prove to be problematic as only four economies have progressed significantly in the development of ENC data although another two are committed to near-term development.
- Satellite communications are currently available in all but two of the eleven economies for which there was information available on communications capabilities.
- A number of APEC economies are currently focussing on implementation of GMDSS and not SN&C technologies such as DGPS and AIS.
- In general, implementation of marine SN&C systems in the region is moving slowly.

SN&C Implementation Issues

- Given the low level of response to this question, the key issues may not be representative of the full APEC region.
- The key potential APEC issues that were identified by the member economies were: Cost and Funding (4/5); Standards and Regulations (3/5); and Harmonization and Seamlessness (3/5).

APEC Actions

- Given the low level of response to this question, the key APEC actions may not be representative of the full APEC region.

- The key potential APEC actions that were identified by the member economies were: Coordination and Planning (4/4); Funding Assistance (3/4); Standards and Regulations (3/4); and Technical Assistance (3/4).

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3. Technology Review

3.1 Introduction

The Technology Review Report (Element 2) provides a broad introduction to the technologies which make navigation and communication possible in the air and marine environments. The emphasis is on navigation; communication is included to the extent that it supports navigation, surveillance and management of air and marine traffic.

The report is directed at those who wish an overview of the technologies and their implications, such as program managers and policy makers. Readers who require technical details on any of these technologies should consult the publications of organizations responsible for planning and standards, such as ICAO, IMO, and IHO.

3.2 Satellite Navigation

The global navigation satellite system will provide high accuracy, integrity and availability, and a continuous, worldwide navigation service for all phases of a journey for both marine and air transportation. It will make it possible to achieve capacity improvements at limited cost. Aircraft and ships will be able to navigate in any part of the world using a single set of navigational instruments. Three- and four-dimensional navigational accuracy will be improved.

The benefits of satellite-based navigation to the aviation community are particularly relevant in the Asia-Pacific Region. The airspaces in this region are often over remote continental or oceanic areas. In these areas, it is often not possible or practical to rely on ground-based systems. Airborne systems, with their inherent accuracy limitations, must be used, often contributing to the need for large separations, thereby reducing capacity. The implementation of satellite-based navigation in concert with other SN&C systems will allow for the reduction of separation standards.

Another potential benefit of satellite-based navigation (with the appropriate augmentation) is the availability of non-precision approaches and Category I approaches. Ground-based navigation systems will not need to be implemented (although upgrades to approach and runway lighting may be needed) to provide these levels of service at airports that currently do not have landing guidance. Category II/III approaches may also be possible with local area DGPS and at a lower cost than microwave landing systems.

Also, for provider economies that have implemented extensive ground-based navigation systems, cost savings may be realized as the existing ground-based navigation aids are no longer needed.

The marine community will also realize benefits from the implementation of SN&C technologies. With the anticipated decommissioning of Loran-C, GNSS will be an important navigation system for marine users. The increased accuracy and availability of GNSS (in conjunction with ENC/ECDIS) will allow operations in areas and weather conditions that may not be possible using conventional aids. The increased navigation accuracy will increase safety under all conditions, potentially reducing groundings and other incidents. As was the case for the aviation community, the marine providers of conventional navigation aids such as lighthouses and buoys may realize cost savings as the number of aids may eventually be reduced.

3.2.1 Global Navigation Satellite System

A Global Navigation Satellite System (GNSS) is made up of three parts: a constellation of navigation satellites (space segment and augmentation facilities), ground infrastructure (control segment), and user receivers (user segment). There are currently two space components of the GNSS: GPS and GLONASS. GPS is operated by the U.S. Department of Defence; GLONASS is operated by the Russian Federation.

The description here will concentrate on GPS since it is fully operational and widely used. GLONASS, while not fully compatible with GPS, is very similar in design and operation. It is expected that, in the future, many receivers will be able to use signals from both systems. The *space segment* is composed of 24 satellites, orbiting with 12-hour periods, such that a minimum of five satellites are in view to users worldwide. The *control segment* has five monitor stations and three ground antennas with uplink capabilities. The monitor stations track the satellites to determine satellite clock and orbit status and then update the navigation message of each satellite. The *user segment* consists of an antenna, receiver and processor which computes position, velocity and precise timing for the user.

The GPS transmits two signals. The Standard Positioning Service (SPS) is available to all civilian users worldwide. It currently provides positioning accuracy in the order of 100m. The Precise Positioning Service (PPS) is available only to the U.S. military and other authorized users. It provides positioning accuracy in the order of 20 m. The SPS accuracy is controlled by the U.S., and is capable of being about as accurate as the PPS.

The concept of GPS position determination is based on the intersection of vectors with known origins and magnitudes. Three-dimensional measurements with time (for velocity) requires four satellites to be in view of the receiver. These measurements are with respect to World Geodetic Systems, 1984 (WGS-84) Earth Centred-Earth Fixed (ECEF) coordinates.

3.2.2 Satellite Navigation Augmentation

The basic GPS signal is augmented to ensure that the requirements for accuracy, integrity, availability and continuity of the signal are met. These requirements may be different depending on the application.

Accuracy is the degree of conformance of an aircraft's or vessel's measured position with its true position. Basic GPS meets the accuracy requirements for en route through non-precision approaches (NPA) but not for precision approaches. For marine applications, the accuracy meets requirements for offshore and open waters but not for confined waters such as ports and inland waterways. The satellite signal can be augmented with additional information to increase the accuracy of the position calculation. There are a number of approaches to this, some of which can obtain accuracies in the order of 1 cm.

Integrity is the ability of a system to provide timely warnings when part or all of the system is providing erroneous information and thus should not be used for navigation. The level of integrity needed is dependent on the application. In general, the aviation community requires a higher level of integrity monitoring than the marine community.

Availability is the probability that at any time the system will meet the accuracy and integrity requirements for a specific phase of flight or vessel movement. Availability is critical for all phases of flight but in particular for take-offs and landings; and GPS does not meet the availability requirements for air transportation. Availability is not as critical for all phases of vessel movements. Only in confined waters does the availability of GPS not meet marine requirements.

Continuity is the probability that a service will continue to be available for a specified period of time, given that it is available at the beginning of the period (for example, that the system will continue to meet the requirements for approach guidance throughout an approach, given that it is available at the initiation of the approach). For aviation, it is of concern primarily in the approach mode of flight (requiring .99995/approach). The marine community typically requires less stringent continuity requirements (ie., .997 percent of the time).

These four requirements are typically met through augmentation to the GPS. For marine, this is typically achieved through Differential GPS systems which improve the accuracy and integrity of the signals. DGPS uses one or more reference stations at geodetically surveyed locations. Each reference station monitors the GPS signal and can compute corrections since it knows exactly where it is. These differential corrections are then transmitted using existing marine radio beacons to GPS user receivers, which apply the corrections to the GPS signals. The DGPS systems also provide integrity monitoring which will warn the user when the service is not functioning properly. For example, the United States and Canadian Coast Guards have implemented a DGPS service for confined waters such as harbour and harbour approach phases of marine navigation. The system covers both coasts of the United States and Canada, including Alaska and Hawaii, the Great Lakes and St. Lawrence Seaway, and the Mississippi River. The system consists of a network of reference stations which broadcast corrections over radio beacons. Accuracy is expected to be better than 10 m in all harbour approaches. Operations are now achieving accuracies on the order of 1 m. The integrity monitoring provides a broadcast of any faulty condition of the GPS service, the DGPS signal or the transmitter within 10 seconds of the fault. Similar DGPS systems are being implemented in Australia, China, and Hong Kong.

To meet the aviation requirements, augmentation is provided using either wide area augmentation systems or local area augmentation systems. For example, the U.S. Federal Aviation Agency (FAA) has begun development of their Wide Area Augmentation System (WAAS). GPS data will be received and analyzed at reference stations. This data will then be forwarded to master stations for processing of corrections. The corrections are then forwarded to earth stations, transmitted to geostationary satellites and broadcast to users. The system will cover all of the United States, including Alaska and Hawaii, and much of Canada. WAAS will provide three services: integrity data on the GPS and GEO satellites, wide area differential corrections for GPS satellites, and additional ranging capability provided by the GEO satellites. WAAS will support aviation navigation for the en route through Category I precision approach phases of flight. For the marine community to make use of WAAS, changes in their receivers will be required. MTSAT in Japan and EGNOS in Europe are proposing to provide similar capabilities in their regions.

The FAA and others envisage using a Local Area Augmentation System to permit Category II and III landings using GPS. One example of LAAS implementation uses a pseudolite (pseudo satellite) located near the runway. The pseudolite transmits very accurate GPS signals, unaffected by orbital decay, ionospheric interference, or errors compounded by distance. These are expected to achieve accuracies measured in centimetres.

3.2.3 Reference Systems, Charts and Displays

Reference Systems
Geodetic datums are reference coordinate systems used to establish the precise geographic position and elevation of features on the Earth. GNSSs use a coordinate system which is relative to the centre of mass of the earth (Earth Centred Body Fixed). The current standard is the WGS 84. This provides a true three-dimensional datum. Other coordinate systems are either horizontal or vertical. There has been a proliferation of such systems over time and across regions. The conversion from these old systems to the new ECBF is not trivial. However, it is important since differences among coordinate systems can vary by as much as 800 m and these differences are not uniformly distributed.

Charts
The present “paper” charts provide no better than a few metres resolution. The positional accuracy of chart features sometimes varies from chart to chart and, in some cases, within a chart. Digital charts will provide greater resolution and accuracy for navigators, and this will be of particular benefit in confined waters. For the first time, the systems upon which marine navigation charts are made and used will be the same.

Electronic displays
The Electronic Chart Display Information System combines both spatial and textual data into an operational tool for the mariner. The IMO performance standard for ECDIS was formally adopted by the Nineteenth Assembly of the IMO in November 1995 as equivalent to paper charts under the Safety of Life at Sea convention.

3.3 Satellite Communications

3.3.1 Aviation

Communication between pilots and air traffic controllers is presently achieved using HF voice radio in oceanic airspace, and VHF voice radio in domestic airspace. VHF radio provides line-of-sight coverage. Because of the lower frequencies used, the HF radio coverage can extend over much greater areas than VHF or UHF radio. However, HF is much more susceptible to interference and variations in coverage owing to atmospheric conditions. Therefore, it is expected that voice communications in remote continental and oceanic areas will move away from HF towards satellite systems such as INMARSAT, MTSAT and PALAPA. The availability of these systems is all the more important in regions such as the Asia-Pacific due to the vast expanses of oceanic airspace. In areas such as the South Pacific, satellite communications, both voice and data, already play an important role in air traffic management.

It is true that satellite voice communication is presently very expensive when compared with HF radio in oceanic areas. However, with the increasing use of satellite voice communication by airline passengers and greater availability of satellite systems, costs will decrease significantly in the future.

In the future, there will also be a shift away from voice communication towards data communication. CPDLC is a critical component of ADS that allows for the reduction of separation standards in airspaces where radar coverage is not available. The exchange of data not only allows pilots and controller to communicate directly but will also allow aircraft flight management computers to directly communicate with ground-based air traffic management computers for coordination and position reporting. Data communications in oceanic and remote airspaces will be primarily by satellite or HF data link.

In domestic airspace, there is a variety of data link options available with three main options: 1) Satellite Data Link, 2) VHF Data Link, and 3) Mode S Secondary Surveillance Radar. At present the most cost-effective option appears to be VHF Data Link. Satellite data linking is unlikely to be used domestically because of its high cost and because of the high data rates with minimal delays required for applications such as position reporting in busy terminal areas.

Mode Select (S) Secondary Surveillance Radars (SSR) are presently being installed in the United States and Europe. Mode S may provide data link capability between the aircraft computer systems and ground air traffic management systems. Aircraft would need to be fitted with the new Mode S transponders which are connected to the aircraft flight management system or a small data link terminal.

VHF data linking consists of a network of ground VHF stations, data routers, and VHF equipment on the aircraft which connects with the aircraft flight management system or a small data link terminal. Character oriented VHF data link systems such as ACARS have been used in the U.S., Canada, and other countries for some years for pre-departure clearances. Standards are being developed for the use of data linking for ATC purposes.

Improved and expanded communications, both voice and data, are key to the implementation of CNS/ATM and the accrual of the benefits. The benefits of data link will include:

- More direct and efficient linkages between ground and airborne systems, resulting in improved air traffic management services;
- Improved handling and transfer of aeronautical communications;

- Reduced radio frequency channel congestion;
- Inter-operable communications media;
- Increased reliability and reduced communications errors, thereby enhancing safety; and
- Reduced workload and improved efficiency for air traffic controllers, flight service specialists, and pilots.

It is anticipated that in the future, international messages will also be exchanged over the new bit-oriented ATN. The ATN is an air-to-ground and ground-to-ground data communications network which allows for full interoperability between different aeronautical systems. Examples of aeronautical systems connecting to the ATN include VHF data link, satellite data link, computer systems on the aircraft, and computers on the ground used for air traffic services, airline control and administration. The ATN architecture is based on the Open Systems Interconnection reference model of the International Standardization Organization.

3.3.2 Marine

The communications systems that ocean-going ships are required to carry are regulated through the GMDSS under the SOLAS convention. The GMDSS is being phased in over the period from 1992 to 1999 and applies to all vessels subject to the 1974 SOLAS convention. SOLAS covers all passenger ships that carry more than 12 passengers on international voyages and all cargo ships of 300 GT and over engaged in international trade.

The equipment that a ship must carry to comply with GMDSS is determined by the area in which the vessel operates. The GMDSS may require ships to carry Search and Rescue (SAR) transponders, Emergency Position Indicating Radio Beacons (EPIRBS) and NAVTEX receivers or a combination thereof. GMDSS includes regulations for the carriage of satellite or HF communications. The regulatory requirements for ships operating within territorial seas and inland waters may vary from country to country. However, VHF would cover most of the inland water communication requirements.

Although a significant number of ships now use satellite communications, the majority still rely on HF or VHF communications. The principal marine satellite communication system in use today is INMARSAT which provides marine communications to approximately 30 000 commercial, private, or government ships around the world from four satellites placed to cover all the major oceans. The number of users is growing dramatically and is expected to reach approximately 90 000 by 1997.

INMARSAT is a partnership of 64 nations providing mobile satellite service. It currently offers four services:

- INMARSAT A is already used extensively for voice, data, image and video communications. It provides good quality service and the only major complaints are the connect time costs and the cost and size of terminals.
- INMARSAT B is a digital replacement for INMARSAT A. It is gradually being put into service. It offers lower costs and improved performance for some applications.
- INMARSAT C is strictly a low-speed data service. It is used for E-mail, emergency situation reporting and low volume data transmissions. It is being used increasingly for automatic position reporting.
- INMARSAT M is a relatively new service. It is not recognized for safety requirements under SOLAS or GMDSS. Its low cost and small size have made it popular for yachts and other small vessels. Briefcase sized terminals are now available.

Approximately 25 percent of the 80 000 large ocean going vessels have installed INMARSAT satellite communications terminals. Only a very small number of vessels under 60 feet have been fitted with satellite communications equipment due to cost and size of equipment.

INMARSAT P will be the follow-on system to the existing INMARSAT satellites. It will be competing with proposed regional and global mobile services such as MSAT and Globalstar, and advanced high bandwidth systems such as Iridium and Odyssey.

In the future, advanced satellites will provide a two-way interactive link for voice, data and multi-media applications with global coverage capability. They will use transportable briefcase sized terminals, small antennas, and stabilizers easily installed on-board ship. Such systems are expected to become available in 1999. These systems are unsuitable for emergency use because of outages due to rain and other environmental conditions.

3.4 Satellite Surveillance

3.4.1 Aviation

The availability of secure communications and accurate navigation systems can be combined to provide global aircraft position information on air traffic management surveillance displays. Such information will meet surveillance needs where radar coverage is not possible or cost-effective. Computer aided air traffic management tools will be added to support improved airspace efficiency.

Surveillance services enable other pilots or air traffic controllers to know the position of aircraft in a specific area of airspace. Currently, either radar or pilot reporting is used to obtain the position of aircraft. Voice position reporting is used outside radar controlled airspace using VHF radios in domestic airspace, and HF radios in oceanic airspace. In the future increasing use will be made of ADS which will enable the automatic periodic reporting of the aircraft position to air traffic controllers via a data link.

Given the substantial benefits that can be achieved from ADS in the region, many economies have already or will soon implement ADS (a non-standard version). Benefits of ADS will include:

- Enhanced safety and reduced delays;
- More efficient use of airspace and increased capacity;
- More accurate tracking of aircraft in a non-radar environment;
- Reduced horizontal separation minima in a non-radar environment;
- Better accommodation of user preferred fight profiles and reduced flight operating costs (if associated Air Traffic Management functionality exists); and
- Increased flexibility and reduced costs of air traffic control operations.

3.4.2 Marine

The development of Automated Identification Systems (AIS) in the marine world is analogous to ADS in aviation. An AIS system requires:

- A means of precise positioning in the area of desired coverage (e.g., GPS or DGPS);
- A suitable communications link; and
- Appropriate processing and display equipment.

An AIS requires that vessels generate navigation (position, course, speed) and other status information, and then report this information to a surveillance centre, typically a Vessel Traffic Services (VTS) Centre, where the information is processed and displayed. The polling and response sequences between the VTS Centre and participating vessels via an AIS communication link are fully automated.

While ADS is likely to become ubiquitous in the aviation world, AIS in the marine world will probably remain in more specialized applications, such as the following:

- Piracy - surveillance would help law enforcement agencies combat piracy.
- Fishing - surveillance would help fisheries management organizations monitor and control exploitation of fish stocks.
- Inventory Management - surveillance would help shipping companies better manage their resources.
- Vessel Traffic Services - surveillance would help harbour masters and coast guards to better monitor and control vessel traffic in congested areas such as harbours and straits.

Before any AIS system can be widely or effectively implemented, it would be necessary for international standards to be established. In this respect, the IMO Sub-Committee on Safety of Navigation is developing performance standards for ship borne AIS equipment using both Digital Selective Calling (DSC) and broadcast techniques. At the July 1996 meeting of the Sub-Committee, proposals for the carriage of this equipment included a two-stage implementation process, with the DSC system being proposed for certain classes of vessels in 1999, followed by a wider application of a broadcast system sometime after 2001.

3.5 CNS/ATM

The aviation community is combining the technical capabilities described above into a system concept known as Communications, Navigation, Surveillance/Air Traffic Management (CNS/ATM). There are significant benefits to be gained from the implementation of CNS/ATM systems. The inherent improvements in communications, navigation, and surveillance will result in improved data handling and transfer among operators, aircraft, and air traffic service providers, global navigation and approach capabilities through GNSS, extended surveillance by ADS and advanced ground-based data processing. The new CNS/ATM systems will also allow a more flexible and efficient use of both en route and terminal airspace.

New CNS systems allow closer interaction between ground systems and airspace users, before, during, and after flight. The full benefits of the new CNS systems will be achieved through ATM automation. The APANPIRG Regional Plan summarized the benefits of CNS/ATM as follows:

- Maintain or enhance the existing level of safety;
- The provision of an ATM system to make more efficient use of airspace and airport capacity and to permit the harmonious treatment of flights transiting all airspace;
- The provision of CNS in a more cost effective manner; and
- The global provision of CNS in a more uniform manner.

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4. Safety Review

4.1 Introduction

Under Element 2 of the study, two reports were produced: i) Expert Panel on Safety Issues - Air Transportation; and ii) Expert Panel on Safety Issues - Marine Transportation. The reports record the results of the two Expert Panel Meetings that addressed issues arising from the implementation and use of SN&C technologies. The Panels were held in support of the international effort by APEC economies to accommodate increasing traffic in a safe manner. This section summarizes the two reports by describing the process used for the expert panels and presenting the key findings.

4.2 Expert Panels

Two Expert Panels were held concerning the safety issues arising from the use of satellite navigation, communications and surveillance, one for marine and the other for air transportation. The Expert Panels considered the following questions:

- *Problem Identification*: What *safety issues* do you think may arise from future communication, navigation and surveillance systems?
- *Problem Prioritization*: Which are the *most important* safety issues?
- *Problem Mitigation*: What are others *doing*? What can APEC do?

4.3 Marine Transportation

The marine transportation Expert Panel considered the safety impact of the following technologies:

Position determination - Global Navigation Satellite System (such as GPS and GLONASS); accuracy and integrity augmentation of the basic satellite signal (such as the Canadian Coast Guard's DGPS); and user equipment for reception and processing of the signal.

Charts, displays, and information updates -electronic charts (ECS and ECDIS) of geographic, hydrographic, and navigational information; updates to the electronic charts by remote communications; and display of dynamic information such as advisory notices, weather, ice, and positions of other craft.

Position communication - Automated Identification Systems (AIS) which use ship transponders to keep Vessel Traffic Services (VTS) and other ships informed of the position of a ship.

Search and Rescue alerting - Emergency Position Indicating Radio Beacons (EPIRBs) which transmit a signal to a satellite indicating an emergency to authorities and indicating the position of the transmitter.

Recommendations for APEC action focussed on the following themes:

- Training,
- Infrastructure,
- Standards, and
- Regulations.

And consisted primarily of encouragement for:

- Cooperation with international organizations, and
- Support of domestic agencies.

4.4 Air Transportation

The air transportation Expert Panel considered the safety impact of the following technologies:

Position determination - Global Navigation Satellite System (such as GPS and GLONASS); accuracy and integrity augmentation of the basic GNSS signal (such as WAAS and LAAS); and avionics for reception and processing of the signal.

Charts, displays, and information updates - electronic charts of geographic, and navigational information; updates to the electronic charts by remote communications; and display of dynamic information such as advisory notices, weather, and positions of other aircraft.

Position communication - Automatic Dependent Surveillance (ADS) which uses aircraft transponders and data communication links to keep Air Traffic Control (ATC) and other aircraft informed of the position and status of an aircraft.

Search and Rescue alerting - Emergency Locator Transmitters (ELTs) which transmit a signal to a satellite indicating an emergency to authorities and indicating the position of the transmitter.

Recommendations for APEC action focussed on the following themes:

- Training;
- Information exchange;
- Standards, procedures and regulations;
- Database and software integrity, and configuration management; and
- Trials and demonstrations.

And consisted primarily of encouragement for:

- Cooperation with international organizations;
- Support of domestic agencies; and
- Political and financial support.

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5. Costs & Benefits Assessment

5.1 Introduction

The Costs and Benefits of Satellite Navigation and Communications for Air and Marine Transportation Report (Element 3) describes a methodology that identifies and quantifies the potential benefits and costs of implementing satellite-based navigation and communication technologies (SN&C). The methodology applies to the aviation and marine sectors for any APEC economy or group of APEC economies and builds on previous work completed by the consultants on Transport Canada's analysis of the implementation of SN&C in Canada and on the approach developed and applied by ICAO to assess the economics of CNS/ATM investments for the aviation sector. Major issues representing constraints to the implementation of SN&C that may be influenced by APEC (guided by the findings and issues given in Section 2) are also presented, along with the impacts they may have on the magnitude or timing of the benefits and costs. These impacts are illustrated by way of hypothetical, but realistic, examples.

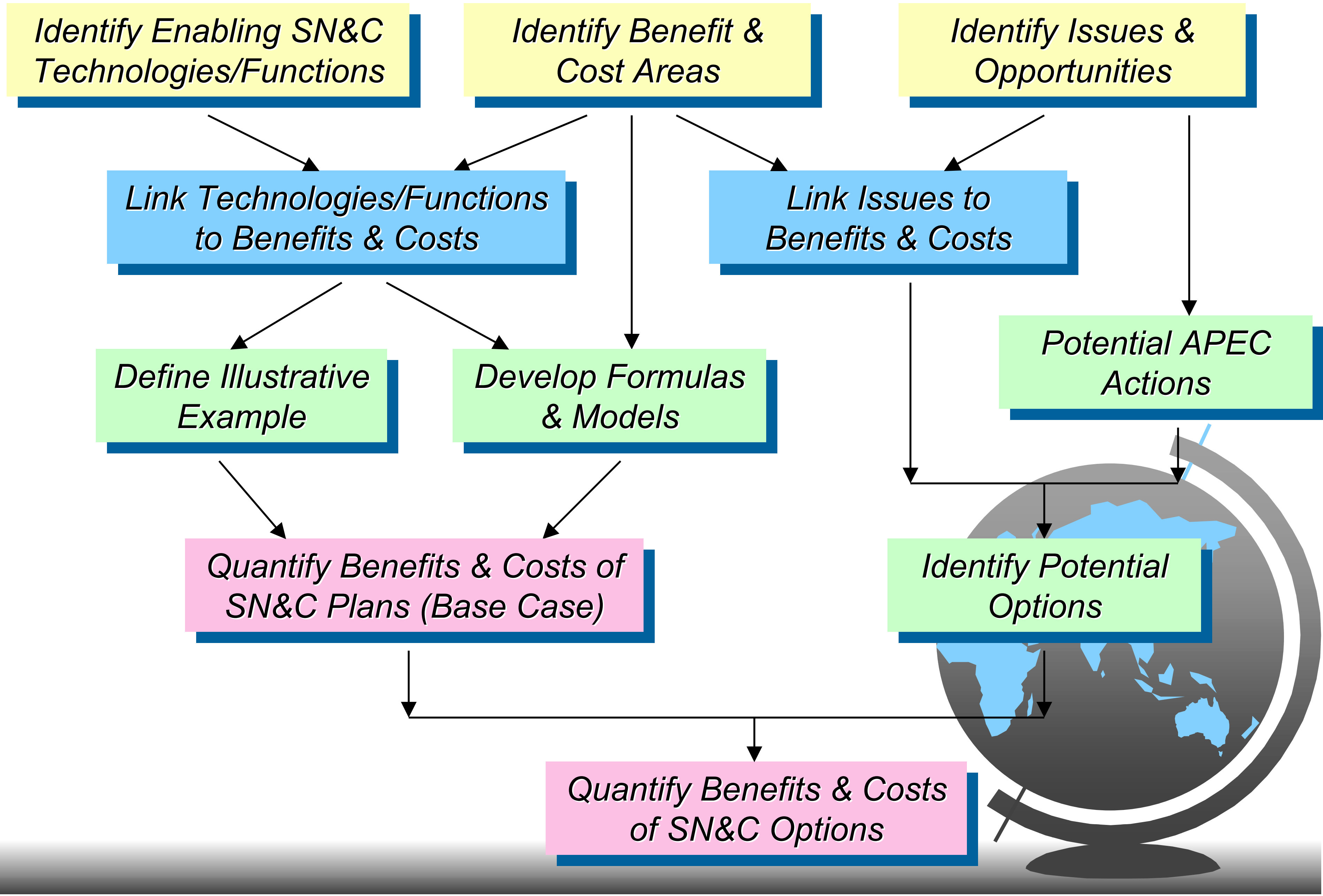
This section presents a summary of the Benefits and Costs of SN&C Report. An overview of the methodology is provided, the illustrative examples are described, and the impacts presented.

5.2 Overview of Methodology

An overview of the approach is presented in Figure 5-1. The process begins with the identification of the benefit and cost areas associated with SN&C implementation. The SN&C technologies and functions that are likely to have an impact on the operations of system users and service providers are then identified and linked to the benefit areas.

The impact APEC can have on the economics of SN&C is assumed via actions that would resolve or mitigate the effects of issues which constrain the timeliness or effectiveness of SN&C implementation. The linkages between the issues identified and the benefits, costs or implementation timing is critical, as these define the potential "levers" for APEC action, and represent the options.

Figure 5-1: Overview of Approach



The quantification requires the development of a computational model with the suitable formulations and metrics for each of the benefit and cost areas. The extent of quantification is limited only by the availability of the required data and resources to conduct such an analysis. For this analysis, it was possible only to illustrate the benefit-cost methodology with a practical and realistic example. Decisions regarding SN&C investments for specific economies and regions will require detailed economic analyses, as each economy or region will have its own set of constraints, policies, and priorities. The report provides a methodology and analysis tool that can be used by individual economies or sub-regions to undertake their own benefit-cost analyses.

The methodology represents a life-cycle approach to benefit-cost analysis. The analysis calls for consideration of all costs related to the investment, regardless of who bears them. As a general rule, all costs that vary as a result of the decision being taken, or which must be incurred for the accrual of benefits, should be included in the analysis.

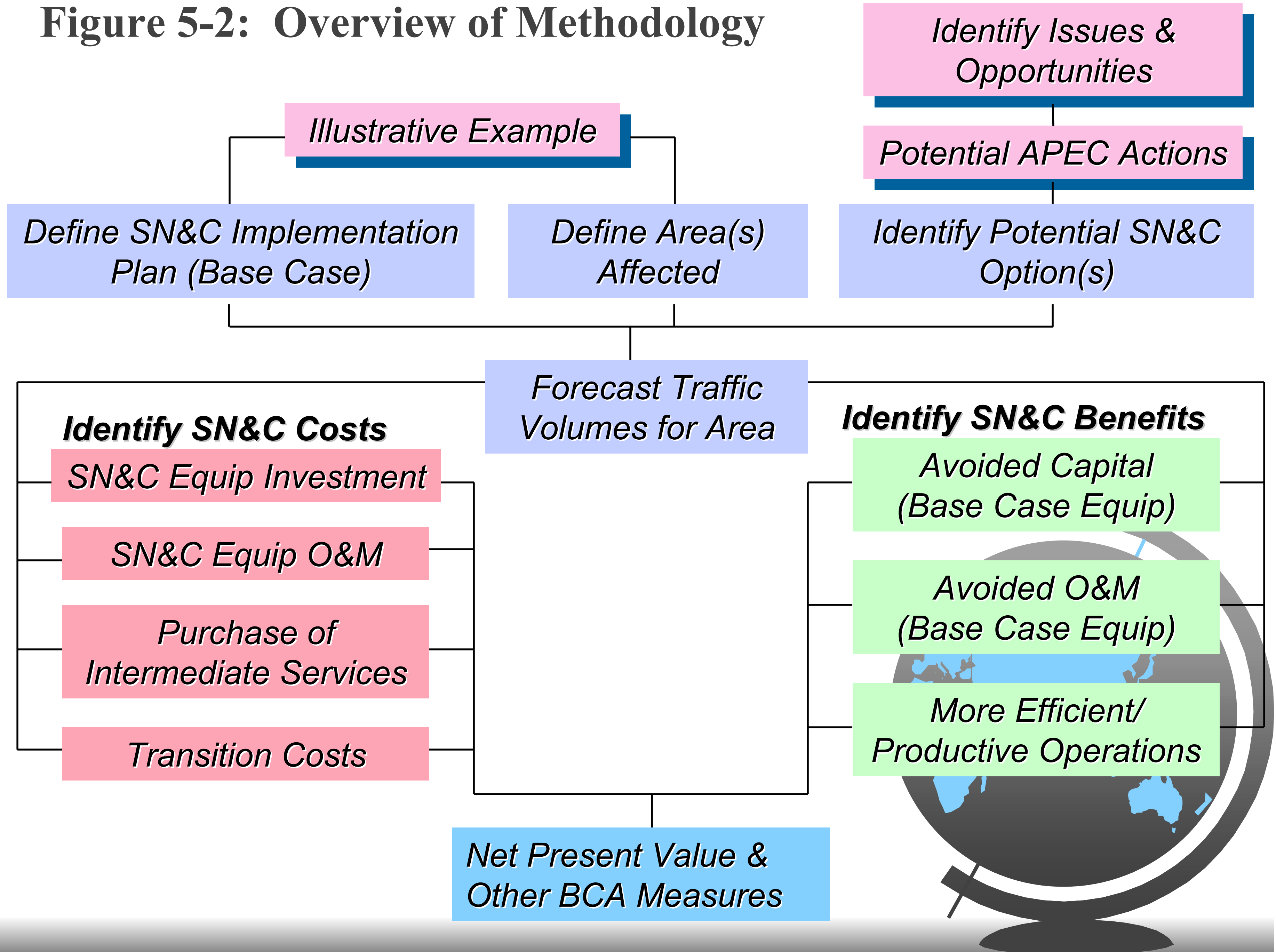
Similarly, the analysis should examine all benefits resulting from the investment regardless of who realizes the benefits. The costs and benefits are estimated over a period representing the useful life of the investment (assumed in this analysis to be 15 years), and a decision is based on the alternative that yields the highest Net Present Value (NPV) measured relative to a “Base Case”. The NPV is the present value of the investment’s benefits minus the present value of its costs. A negative NPV for all identified options suggests that the Base Case option is the best one to pursue from an economic perspective.

An overview of the methodology is presented in Figure 5-2.

The Base Case option represents the baseline against which to compare the options. In this instance, it is represented by the forecast SN&C investment profile without APEC involvement, and is specified by the current implementation plans for the region (or economies) being considered. For aviation, the plans could include the further development of RNAV routes using GNSS, ADS in Oceanic areas, and improved navigation capability at airports with no or non-precision approach aids using RAS. The marine sector plans may include development of DGPS capabilities, supported with ECDIS for confined waters.

The options are defined by the potential APEC initiatives regarding the key implementation issues that can affect the magnitude or timing of the benefits and costs. APEC may assist through funding, promoting coordination/harmonization, education or provision of technical assistance in planning and development of procedures.

Figure 5-2: Overview of Methodology



The costs of SN&C implementation can be grouped into the following categories:

- **SN&C research and development costs**, which should include all costs incurred prior to procuring the system under evaluation, except those costs that have already been incurred at the time the analysis is undertaken. These are considered sunk costs, and should not be included in the analysis.
- **SN&C equipment investment**, which identifies the capital costs of the SN&C technologies, including delivery and installation costs.
- **SN&C operating and maintenance costs**, representing the incremental recurring costs required to operate and maintain the proposed investment project. These costs may occur annually or periodically every so many years. The major O&M costs include personnel, materials, utilities, and other (e.g., travel and recurring/refresher training).
- **Purchase of Intermediate Services**, such as satellite communications, data link services, aeronautical telecommunications network, ground communication links.
- **Transition costs** may include planning, system redundancy costs (i.e., existing and satellite-based equipment operating in parallel), cost for decommissioning of systems being replaced, operations and maintenance training, testing and certification, staff redeployment and disruption to operations.
- **Other** (Intangibles), such as impact on safety, or environmental impact such as environmental control, which are often difficult to quantify, but should be identified and described as they may affect the outcome of the decision-making process.

The benefits originate from the implementation of various SN&C technologies or functions by affecting operations in some way. The benefits generally correspond to one of the following categories:

- **Avoided Base Case costs** (**after transition**), which include both capital, and operating and maintenance costs of the Base Case infrastructure no longer required under the SN&C Case.
- **Operational Efficiency/Productivity gains**, either through time savings, or through achieving an ability to perform a particular function with fewer resources (e.g., aircraft, vessels, crew, aircraft fuel, air traffic controllers).
- **Other Benefits** (**intangibles**), such as impact on safety, or environmental impact such as fuel spills, aircraft noise and pollution, which are often difficult to quantify but should be identified and described as they may affect the outcome of the decision-making process.

The benefits and costs described above may accrue to any one of the three major stakeholder groups as follows:

- **Service Providers**, which include State Civil Aviation Authorities (CAAs), State Marine Transport Authorities (MTAs), and intermediate service providers which usually operate under commercial principals.
- **Service Users**, including aircraft operators (airlines and general aviation), vessel operators, and their passengers and shippers (consignees).
- **Society**, for external effects such as environmental and macro-economic effects.

The benefits are of the following types (most apply to both aviation and marine sectors).

Increased Operating Conditions (Incremental Operations)
This benefit area concerns situations where the current navigation capability does not allow aircraft operations to occur during poor meteorological conditions (i.e., periods below a specified minimum visibility constrained by the current technology equipment and procedures). The implementation of SN&C may improve the navigation capability, increasing the opportunities/conditions that allow continued operations, and reducing the costs associated with cancellations, delays and reroutings.

Fewer Service Disruptions
This benefit type represents a form of the type described above. The implementation of SN&C technologies may improve the reliability of the navigation system (i.e., improve continuity of service), reducing the occasions when the trip is cancelled, rerouted or delayed.

More Direct/Efficient Routings (aviation only)
The potential benefits of this type originate from more fuel efficient flight paths, and the ability to dynamically change routings with changing conditions (e.g., weather, traffic), more direct flight paths since air routes will no longer be constrained by the location of terrestrial en route navigation aids, and fewer ATC imposed restrictions due to congestion or special use areas (i.e., military).

Reduced Congestion
Improvements in surveillance capabilities may allow a reduction in current lateral, in-trail and vertical separation minima for aircraft. This will allow increased availability of routes closer to the preferred altitude and track, resulting in smaller associated “penalties”, and less delay for a preferred track to become available at economical jet altitudes. For marine operators, congestion may be reduced and operational efficiencies gained in confined waters such as ports and channels.

Reduced Aircraft Operator Avionics & Administration (aviation only)
Increased automation and communications (e.g., CPDLC) may improve the productivity of the airlines, resulting in fewer resources required to maintain the desired level of service. For example, data link communications could help the flight planning function by allowing the uploading of new flight plans in remote areas. There will also be a potential reduction in on-board avionic systems required, with associated decrease in spares and maintenance costs.

Improved Fleet Utilization (marine only)
For commercial cargo operators, satellite communications and navigation should allow better monitoring of an operator's fleet, improving fleet management and flexibility in a vessel's itinerary. This should, in turn, improve the utilization of the fleet (i.e., larger loads, less dead-heading, less idle time). For fishing vessels, improved navigation capability may improve the operator's ability to locate/return to fishing areas and safely return to port when the weather deteriorates, leading to increased catches during the often limited fishing season.

Reduced Conventional Infrastructure
Satellite-based navigation and communications technologies may reduce the need to maintain, operate and replace conventional systems if they are rendered supplemental or redundant. The result is an avoided cost to the providers of these facilities.

Improved Service Provider Productivity
Increased automation and improved communications will enhance the productivity of provider services, resulting in fewer resources required to maintain a desired level of service. For providers of marine services, the use of GNSS should improve their ability to position aids to navigation.

Improved Search and Rescue
Better navigation and communication will generate benefits for SAR in two ways: a) more effective search and rescue, resulting in fewer losses; and b) increased productivity of the SAR provider.

Enhanced Safety
Where accuracy, availability and reliability are improved over current systems, there may be some enhancement to safety in the form a reduced risk of an incident, and their associated costs (loss of life, property damage, loss of use).

Increased Environmental Protection
Reduced fuel consumption, fewer incidents and improved SAR should lead to reduced environmental damage.

Tables 5-1 and 5-2 summarize the benefits, and the airway and waterway types in which they are most likely to occur, for the aviation and marine sectors, respectively.

Table 5-1: Potential Aviation Benefits (shaded cells)

Aviation Benefit Type	**Airport/ Terminal**		**Continental Route**		**Oceanic**
	Radar	**No Radar**	**Radar**	**No Radar**	
A1. Increased Operating Conditions					
A2. Fewer Service Disruptions					
A3. More Direct/Efficient Routings					
A4. Reduced Airspace Congestion					
A5. Reduced A/C Operator Avionics & Administration					
A6. Reduced Terrestrial Infrastructure					
A7. Improved Service Provider Productivity					
A8. Improved SAR					
A9. Increased Safety					
A10. Increased Environmental Protection					

Table 5-2: Potential Marine Benefits (shaded cells)

Marine	**CONFINED WATERS**		**Open Waters**	**Off Shore**
	Radar/VTS	**No Radar/VTS**		
M1. Increased Operating Conditions				
M2. Fewer Disruptions				
M3. Improved Fleet Utilization				
M4. Reduced Congestion				
M5. Improved Crew Productivity				
M6. Reduced Infrastructure				
M7. Improved Service Provider Productivity				
M8. Improved Search & Rescue				
M9. Enhanced Safety				
M10. Increased Environmental Protection				

Implementation issues, as described in Section 2, may have an impact on the accrual of benefits and the implementation costs. Issues that are common to both the aviation and marine sectors are: Harmonization of Capabilities and Implementation Timing; Duplication of Equipment and Services; Availability and Application of Standards; Training; Funding Requirements; and Technical Assistance.

The issue specific to the marine sector is the availability of a backup to ECDIS. This issue concerns the identification of an appropriate redundant system as a back-up in case of ECDIS failure. If this issue remains unresolved, a delay in the full benefits of ECDIS implementation could result and the costs to both users and HOs for having to produce both paper and electronic charts could be substantial.

The following issues are critical as they may affect those described above: Sovereignty; Political Will and Commitment; User Acceptance; and Understanding of Costs and Benefits.

The analysis of APEC actions centres on the issues that may affect the benefits and costs of SN&C and how APEC may influence these. The specific linkages of the key issues to the benefits, costs and timing are presented in Tables 5-3 and 5-4 for the aviation and marine sectors, respectively.

Table 5-3: Linkage of Issues to Benefits, Costs and Timing -- Aviation

Issues that may Impact Benefits, Costs and/or Implementation Timing	Benefit Area (A)										Costs	Timing of Implementation
	1	2	3	4	5	6	7	8	9	10		
Lack of Harmonization			●	●	○				○	○	○	●
Duplication of Systems					○						●	○
Lack of Standards									●		●	●
Lack of Training											○	●
Lack of Funding												●
Lack of Certification (Equip & Avionics)												●
Lack of Technical Assistance											○	●
Slow Rate of User Implementation	○	○	●	●	●	●	○	○	●	●	●	○

A1. Increased Operating Conditions
A2. Fewer Service Disruptions
A3. More Direct/Efficient Routings
A4. Reduced Airspace Congestion
A5. Reduced Aircraft Operator Avionics
A6. Reduced Terrestrial Infrastructure
A7. Improved Service Provider Productivity
A8. Improved Search and Rescue
A9. Enhanced Safety
A10. Increased Environmental Protection

● - Major Impact
○ - Minor Impact

Table 5-4: Linkage of Issues to Benefits, Costs and Timing -- Marine

Issues that may Impact Benefits, Costs and/or Implementation Timing	Benefit Area (M)										Costs	Timing of Implementation
	1	2	3	4	5	6	7	8	9	10		
Lack of Harmonization	○	○	○	○	○	○	○	○	○	○	●	●
Duplication of Systems											●	
Lack of Standards									●	●	●	
Lack of Training									●	●		
Lack of Funding												●
Lack of Redundancy (ECDIS)									●	●	●	
Slow Rate of User Implementation	○	○	○	●	○	●	○	○	●	●	●	●

M1. Increased Operating Conditions
M2. Fewer Disruptions
M3. Improved Fleet Utilization
M4. Reduced Waterway Congestion
M5. Improved Crew Productivity
M6. Reduced Existing Infrastructure
M7. Increased Service Provider Productivity
M8. Improved Search and Rescue
M9. Enhanced Safety
M10. Increased Environmental Protection

● - Major Impact ○ - Minor Impact

5.3 Illustrative Examples and Results

Two hypothetical examples were defined, one for each of the aviation and marine sectors, in order to illustrate the impact of APEC actions on the economics of SN&C implementation. Due to difficulties in acquiring the required data, the quantification was completed only for the aviation example.

The example was designed to "create" circumstances that revealed the issues described above. The Base Case in the example was represented by the implementation plans as described in the Inventory Report. The analysis of the Base Case is compared to the status quo or "do nothing" case, and is the starting point against which APEC actions can be measured.

Table 5-5 presents a high level summary of the analysis Base Case results for the hypothetical example. It shows a net present value with a 10 percent discount rate of $352 million. Of greater significance is the resulting benefit cost ratio of almost 3:1.

Of the $627 million in benefits, three-quarters is attributable to the system users through improved operating efficiencies and reduced congestion, and less than 10 percent accrues to the service provider in the form of reduced terrestrial infrastructure and productivity gains. At the same time, SN&C fleet avionics investments represent almost two-thirds of the total cost of implementation. The aviation system users, therefore, appear to have the most to invest **and** gain from the implementation of SN&C. It is not difficult, therefore, to conclude which stakeholder will be the most significant force in driving decisions regarding SN&C implementation.

Table 5-5: Results of SN&C Implementation for the Example System ($ Millions 1995)

Discount Rate	7 Percent	10 Percent	13 Percent
PV Total Benefits	834	627	481
PV Total Costs	323	275	238
Net Present Value	511	352	243

Options were developed which characterize the combined impact APEC could have on the magnitude and timing of the Base Case benefits and costs through the resolution of the issues described in Section 2 and listed above. As a result, the options were presented in terms of the different "levers" that could be positively impacted, as follows:

Option 1 - The example suggests that the implementation timing of SN&C ground components, while realistic, was optimistic considering the potential difficulty Economy "X" would have in funding and training. One impact of APEC action would be to reduce the risk of any delays to SN&C implementation of both ground infrastructure and user SN&C avionics.

Option 2 - The example indicates that one of the neighbours of Economy "X" is moving slowly towards implementation of SN&C. This has a negative impact in the Base Case on potential route efficiency gains. Advancing the implementation schedule of this economy would improve the route and congestion benefits of SN&C. APEC may help to harmonize the implementation among these neighbouring economies within the region.

Option 3 - The example Economy "X" will include its own RAS and ground earth station (GES); infrastructure it should be able to share at much less expense with its more advanced neighbour, Economy "Z". Moreover, better coordination of training, planning and procedures development should also reduce some of the transition costs assumed in the Base Case. APEC may provide a pivotal role in such coordination and cooperation.

Table 5-6 summarizes the results of the potential influences brought about by APEC action on the aviation example. The table presents the **potential** Net Present Value associated with a one- and two-year delay in implementation, improving the harmonization of implementation in the region to provide a more seamless operating environment, and the potential cost impact of unnecessary duplication.

Table 5-6: Potential Impact of APEC Action on the Economics of SN&C ($ Millions 1995)

Option	Discount Rate	7 Percent	10 Percent	13 Percent
	Net Present Value			
	Base Case	511	352	243
1	One-Year Delay	467	315	211
1	Two-Year Delay	424	280	183
2	Harmonization	589	411	288
3	Duplication	551	389	277
	Difference in NPV			
1	Avoid One-Year Delay	44	37	32
1	Avoid Two-Year Delay	87	72	60
2	Harmonization	78	59	45
3	Duplication	40	37	34
	Total (with no 2-yr delay)	**205**	**168**	**139**

The combined effect of the three independent options resulting from APEC action may improve the net present value of SN&C implementation by as much as $130 to $170 million, or about a third of the Base Case NPV. Clearly there are significant potential net benefits to be achieved from the implementation of SN&C, and APEC can influence how and when they are accrued.

The options summarized in Table 5-6 illustrate how dramatic an effect seemingly small impacts could have on the benefits and costs of SN&C. This is due largely to the current inefficiencies experienced by the users, and the tremendous growth in traffic projected for the region. As a result, the opportunities for improvement are significant, and APEC can play a role by assisting member economies in seizing them.

Appendix

Acronyms

A	
ADS	Automatic Dependent Surveillance
AIS	Automatic Identification System
APANPIRG	Asia-Pacific Air Navigation Planning and Implementation Regional Group
APEC	Asia-Pacific Economic Cooperation
ATC	Air Traffic Control
ATN	Aeronautical Telecommunications Network
C	
CNS/ATM	Communication, Navigation, Surveillance/Air Traffic Management
CPDLC	Controller-Pilot Data Link Communications
D	
DGPS	Differential GPS
DSC	Digital Select Calling
E	
ECDIS	Electronic Chart Display Information System
ELT	Emergency Locator Transmitter
ENC	Electronic Navigation Chart
EPIRB	Emergency Position Indicating Radio Beacon
F	
FAA	Federal Aviation Agency
G	
GDP	Gross Domestic Product
GES	Ground Earth Station
GLONASS	Global Navigation Satellite System (Russian Federation)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System

H	
HO	Hydrographic Office
I	
ICAO	International Civil Aviation Organization
IHO	International Hydrographic Organization
IMO	International Maritime Organization
INMARSAT	International Maritime Satellite Organization
L	
LAAS	Local Area Augmentation System
LNG	Liquid Natural Gas
N	
NPV	Net Present Value
P	
PPS	Precision Positioning Service
R	
RAS	Regional Augmentation System
RCC	Rescue Coordination Centre
RENC	Regional ENC Coordination Centre
S	
SAR	Search And Rescue
SARPS	Standards And Recommended Practices
SN&C	Satellite Navigation and Communication
SOLAS	Safety Of Life At Sea
SPS	Standard Positioning Service
T	
TEU	Twenty-foot Equivalent Unit
TPT	Transportation Working Group
W	
WAAS	Wide Area Augmentation System
WEND	Worldwide ENC Database
WGS-84	World Geodetic Reference System 1984