CHINA'S PERSPECTIVES

ON

AIR TRAFFIC MANAGEMENT

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Rusty E. Shughart
Major, U.S. Air Force
Defense Language Institute Foreign Language Center
Presidio of Monterey, California
DLIFLC Washington Office

* * * * *

Institute for National Security Studies
U.S. Air Force Academy
Colorado Springs, Colorado

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HQ USAFA/DFES
USAF INSS
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USAF Academy, CO 80840

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HQ USAFA/DFES
USAF INSS
2354 Fairchild Dr., Ste 5L27
USAF Academy, CO 80840

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China's Perspectives on Air Traffic Management is a research product. In three chapters, it outlines China's current ATM environment, describes CAAC's vision of China's vision of China's future ATM architecture and examines the ongoing programmatic initiatives to bride the gap between these two very different environments. By drawing principally upon Chinese language sources – nearly 100 periodical items, briefings and official news releases- this report characterizes China's perspectives on the technical and practical aspects of the ATM challenges and opportunities it now faces. It also addresses the many peripheral factors that provide the operational backdrop for effects to efficiently resolve China's ATM development issues.

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PREFACE

Over the past 30 years, the General Administration of Civil Aviation of China (CAAC) has led a remarkable transformation of China's civil air transportation industry. As China faces the new millennium, its aviation professionalism, efficiency and safety levels are rapidly approaching global standards, an extraordinary achievement for a nation that had only a rudimentary jet transport industry in 1970.

Despite the remarkable progress of the civil aviation industry as a whole, China still faces the complexities of designing and constructing a modern air traffic management (ATM) system. Its outmoded, ground-based air traffic control (ATC) infrastructure is only marginally capable of providing the support services the civil air transportation industry now requires. In the near future, China must marshal the advanced capabilities of aviation communication, navigation and surveillance into a coherent, national ATM system. Much work remains to be accomplished before China can forge its aviation philosophy and field the systems to simultaneously satisfy domestic ATC requirements and meet global aviation standards as determined by the International Civil Aviation Organization. To realize these dual objectives, China – principally through CAAC – must orchestrate the coordination of a wide variety of organizations with interests in the direction and pace of the nation's ATM development.

China's Perspectives on Air Traffic Management is a research product. In three chapters, it outlines China's current ATM environment, describes CAAC's vision of China's future ATM architecture and examines the ongoing programmatic initiatives to bridge the gap between these two very different environments. By drawing principally upon Chinese language sources – nearly 100 periodical items, briefings and official news releases – this report characterizes China's perspectives on the technical and practical aspects of the ATM challenges and opportunities it now faces. It also addresses the many peripheral factors that provide the operational backdrop for efforts to efficiently resolve China's ATM development issues.

China's Perspectives on Air Traffic Management is intended to be a unique resource aviation policy and defense analysts can call upon for a fundamental description of how the ATM revolution has taken place in China as well as what can be expected in the future. Readers are invited to contact the author for recommendations on improvement or emendation.

Rusty E. Shughart
Major, U.S. Air Force
Arlington, Virginia
1 October 1998

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China's Perspectives on Air Traffic Management

Chapter 1

Perspectives on the Current ATM Environment

* * * *

"Ensure safety first, improve service, and strive for flight responsibility."
-- Premier Zhou Enlai

Overview. By their very nature, the philosophy and initiatives of civil air traffic management (ATM)[1] are complex issues. On one hand, modern ATM requires conservative, sophisticated conceptualization and the ability to transform intricate concepts into coherent plans of action. On the other hand, it demands teamwork from a wide assortment of organizations and specialists to resolve the functional, ongoing challenges of air safety, security and operational efficiency. Together, these forces operate among the operational backdrop of the national political and economic environment, often influenced as much by developments in these fields as by true ATM technical challenges or opportunities.

Similar to most nations around the globe, China's current ATM system is a product of a wide variety of influential forces. However, China also faces unique additional ATM challenges due to peripheral factors such as the size and expanse of its air space; its limited national technical capability; its international political standing; and its bureaucratic and cultural environment. These circumstances combine to form a management philosophy that adds additional levels of conservatism to China's efforts to integrate and utilize the complex systems of ATM. Among the developed nations of the world, there is an ongoing evolutionary transition from conventional air traffic control (ATC) to satellite-based ATM. However, for China, this transition is a much more revolutionary, long-term process that will well exceed the task of merely designing and constructing a national ATM architecture. The requirement for functional collaboration among many management echelons is an equally daunting task China now faces in addressing its current and future ATM requirements.

Since beginning to develop a viable jet transportation industry in the early 1970's, the General Administration of Civil Aviation of China (CAAC)[2] has led a remarkable

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[1] Throughout this paper, the notion of "Air Traffic Management," or ATM, represents the broad definition of communication, navigation and surveillance and ATM concepts (CNS/ATM) applied to national civil air traffic control (ATC) issues. In its narrow definition, ATM includes air space management (ASM), air traffic flow management (ATFM) and air traffic services (ATS). ATS includes flight information services (FIS), ATC and air weather services (AWS); it also includes support services related to emergency reporting and to search and rescue operations.

[2] CAAC, often referred to as the Civil Aviation Administration of China, is China's supreme aviation authority. CAAC serves China as the department in charge of civil aviation affairs under the direct leadership of the State Council. It formulates civil aviation guidelines and policies; promulgates and supervises rules and regulations; oversees the adjustments, controls and evaluation of aviation enterprises; coordinates the procurement of aircraft; supervises flight safety and airworthiness; and manages civil flight routes, airports and colleges. It also conducts civil air-related negotiations and issues certificates of airworthiness and licenses for

transformation of air travel in China.[3] As the new millennium approaches, there are two major factors – each a prime catalyst in the development of China's civil aviation since 1970 – that now call for the natural transition from ATC to ATM: an expansion of air routes and scheduled flight operations and China's air safety and security record.

Growth and Expansion of Air Routes and Scheduled Flight Operations. Generally, national economic and organizational reforms have been the primary impetus for the expansion of air routes and scheduled flight operations in China. Conversely, with few exceptions, political factors and insufficient civil-military cooperation have limited the natural maturation of China's civil air route network.[4]

Positive Factors. The positive forces influencing China's civil aviation route development include economic initiatives and organizational reform.

Economically, the national policy of "economic reform and opening to the West,"[5] adopted under Deng Xiaoping's leadership in 1978, fostered a significant development of China's civil air route structure. This formula validated China's contacts with Western nations in trade, business and, most importantly, tourism.[6] China coupled its tourism emphasis with the development of Special Economic Zones (SEZ's), a series of coastal areas open to Western investment, underwritten by special foreign investment policies mandated by the Chinese Government. The development of the SEZ's also required the support of modern jetliners and civil air services to these outlying regions.[7]

National organizational reform has served as an additional catalyst in the expansion of China's air route structure, the most significant case being the reform of CAAC itself. In 1984, China implemented a national policy of "separating government functions from business management."[8] In civil aviation, this led to the creation of new airlines and airports with much greater autonomy in operational decision-making. The new policy fostered subsequent reorganizations to largely remove the central government

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qualified personnel. Many of CAAC's activities and initiatives are described throughout this paper. For more information, see the numerous citations for CAAC and Air China, China's primary international flag carrier airline, on various Internet sites.

[3] For an overview of the modern development of China's civil aviation industry, see Rusty Shughart, "China's Civil Aviation Industry: Modernization, Technology Transfer and National Defense", *U.S. Air Force Institute for National Strategic Studies*, 1 October 1996, 211 pages.

[4] One notable exception – an instance where political upheaval *benefited* civil aviation – stems from the Great Proletarian Cultural Revolution. During the Red Guard campaign of 1967, much of China's scheduled railway traffic was diverted to support leftist political causes. In response, China relied on CAAC to ensure that crucial transportation requirements would continue to be met. CAAC's flight operations in 1967 outstripped all the major targets of China's state plan and its transport activity "reached an all-time record high." See *The Far Eastern Economic Review Yearbook – 1968*, p. 162.

[5] In Chinese, this policy is "gaige kaifang."

[6] The tourism industry has been a primary source of foreign currency for China since the mid-1970's; it was also a major factor in the acquisition of modern airliners and the expansion of civil air routes throughout China. See "China Hopes to Quadruple Tourists by Year 2000", *The Associated Press*, 6 June 1986. This article quotes a government tourism official who notes that China planned to increase its tourist facilities and improve services in the hopes of quadrupling the number of foreign tourists who visit annually to 12 million by the year 2000. The official added that 3 million foreign tourists visited China in 1985, an increase of 20 percent over 1984 and three times the number in 1978; China earned $1.25 billion from tourism in 1985, prompting CAAC to undertake the construction or renovation of 70 new airports across the country.

[7] See "Flights to All Open Cities by 1986", *Xinhua New China News Agency*, 27 November 1984. In this report, CAAC Director General Shen Tu announced that air services would be available for all of China's 14 open coastal cities, four SEZ's and Hainan Island by 1986.

[8] In Chinese, this policy is "zheng-qi fenli." It replaced the policy of unifying government and commercial ventures ("zheng-qi heyi"), which new China adopted shortly after its creation in 1949. See China Today: Civil Aviation Industry, 1989, 650 pages (in Chinese).

from management processes and inject regulated competition into the civil air industry.[9] By 1987, the reform was well underway, sponsoring a proliferation of new airlines, airports and air service providers.[10]

Negative Factors. The negative forces influencing China's civil aviation route development include political issues and an inadequate degree of civil-military cooperation in the management of air space and air space assets.

Politically, the fallout from the military crackdown on the student-led democracy movement at Tiananmen Square in June 1989 severely constrained the growth of tourism in China, temporarily reducing scheduled flight operations; financially, China achieved only about two-thirds of its targeted tourist industry revenue in 1989.[11] CAAC subsequently reduced the frequency of its domestic flights, although for political reasons it continued to operate most of its international routes despite very low load factors.[12] Operationally, CAAC's direct-subsidiary air transport enterprises achieved less than 89 percent of the 1988 standard in its total ton-kilometers and passenger volume for 1989, falling far short of projected targets.[13] Another key political issue limiting the civil air route structure is the unresolved status of proposed direct air links with Taiwan.[14] This overture, which promises to be a major force in shaping the air route structure of China and the entire Asia-Pacific region,[15] remains a politically charged issue, tied to the problem of the greater Sino-Taiwan relationship.[16]

Over the years, China's military[17] has generally supported the development of civil aviation in China. In fact, the modern heritage of civil aviation in China stems principally from the pillar of national military aviation roles and functions. For example,

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[9] This policy allowed local airport authorities to construct facilities and import advanced technology and equipment from international suppliers, a decentralized process which has largely resulted in the complex ATC/ATM integration challenges CAAC faces today. See "China's Civil Airports Open to All Airlines", *Xinhua New China News Agency*, 13 February 1987, and "CAAC to Pursue Management Reform", *Xinhua New China News Agency*, 18 January 1988.

[10] CAAC Director Shen Tu originally announced the civil aviation reform in late-1984, during a meeting commemorating CAAC's 35th anniversary. Shen called for the creation of five airline companies operating separate international and domestic services, noting that this initiative was "the first overall and fundamental reform of the CAAC managerial system since 1949." He added that the civil aviation departments would have more investment and greater decision-making power, including the authority to obtain bank loans and foreign funds for modern equipment. Local governments were encouraged to buy aircraft; build airports and service facilities; and set up joint companies. See "Five New Airline Companies to be Established", *Xinhua New China News Agency*, 2 November 1984.

[11] In 1989, China's tourism revenue was approximately $1.7 billion, compared with $2.2 billion in 1988 and short of the government's target of $2.5 billion. See "The Fall-out from Tiananmen - Sanctions have Severely Hit China's Inefficient Aviation Sector", *The Financial Times Limited*, 5 February 1990, p. IV. This article also describes several ancillary problems affecting civil aviation as a result of Tiananmen. First, U.S.-imposed sanctions on China delayed the delivery of three Boeing 757's because their sophisticated navigational systems had potential military use. Second, China's overall credit rating among international financial markets dropped significantly, increasing the cost of borrowing to finance new aircraft purchases.

[12] *Ibid.*

[13] See "CAAC Continues to March Forward", *International Aviation*, April 1990, p. 8.

[14] In January 1979 (on the eve of the lunar new year), CAAC proposed negotiations with Taiwan civil aviation authorities on an air service agreement, indicating a willingness to establish direct air links between Mainland China and Taiwan. In November 1979, CAAC offered to exchange aeronautical information with Taiwan, citing a joint use of technical data to develop civil aviation and ensure flight safety. See "Chinese Call for Air Service Between Mainland and Taiwan", *Xinhua New China News Agency* (in English), 4 January 1979.

[15] Based on an interview with Mr. C.C. Hsin, Director of International Programs, *Mitre Corporation*, on 23 December 1997.

[16] The proposal for direct air routes is a major initiative of intermittent discussions on Sino-Taiwan relations. The Straits Exchange Foundation (SEF) represents Taiwan's interests; the Association for Relations across the Taiwan Straits (ARATS) represents Mainland China. These talks are often suspended as part of the political fallout of other issues, such as civil air hijacking incidents and military aircraft defections across the Taiwan Strait.

[17] The People's Liberation Army, or PLA. Generally, the PLA can refer to the PLAAF and, to some extent, the PLA Navy Air Force (PLANAF).

in 1984 the People's Liberation Army Air Force (PLAAF) permitted CAAC to use 40 military airfields for civil air service.[18] In addition, PLAAF transport units reportedly flew over 700 sorties that year to help transport the commodities of foreign trade departments throughout China, augmenting CAAC's air cargo delivery efforts.[19] This action later led the PLAAF to establish its own commercial air operation, China United Airlines.[20] The PLAAF also assisted CAAC by training air traffic controllers at the Navigation Institute of the Air Force until CAAC could consummate its domestic and international ATC training initiatives.[21]

Since the mid-1980's, the consistent growth and expansion of China's civil aviation, coupled with the general decline of the role of the military in the post-Cold War period, led the PLAAF to be less supportive of CAAC operations. Problems began to develop as early as 1986 with a State Council edict expanding CAAC's operational control to all civilian flight activities.[22] Additionally, by early-1994, pilot retention emerged as a PLAAF concern as the career enticements of the commercial airline industry induced greater numbers of military pilots to join the civil ranks.[23]

Perhaps most significantly, substantial differences developed between the PLAAF and CAAC over China's air route network. The military, which as a core competency controls nearly all of China's air space, became increasingly reluctant to designate additional air routes for civilian use, particularly considering CAAC's poor air safety and security record. To adjudicate air route matters – essentially, to de-conflict the air operations of more than 10,000 military and civil aircraft – the State Council in September 1985 created an ad hoc task force, known as the State Air Traffic Control Committee.[24] A former CAAC deputy director led this body, reporting directly to the State Council and responsible for modernizing China's air management system and unifying its civil-military elements. The Air Traffic Management Bureau (ATMB) serves as the executive council of the committee. Its initial tangible success came in late-1987, as the PLAAF began to relinquish part of its route network in eastern China. However,

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[18] Later, following several collisions between civil airliners and military aircraft and following the rapid development of civil airports across China, the routine utilization of dual-use airfields greatly subsided.

[19] PLAAF involvement in civil transport issues was reportedly in line with Deng Xiaoping's instruction to "aid state construction by subordinating military work to the overall situation of state construction." See "PLA Air Force Aids State Economic Construction", *Xinhua New China News Agency*, 13 November 1984.

[20] China United Airlines (CUA) is an off-shoot of a PLAAF independent transport unit which in 1986 generally provided VIP services to China's leadership and special charter flights with about 60 aircraft. See Robert Thomson, "Chinese Army in Air Venture", *Financial Times*, 14 June 1986, p. 2. Note that CUA has subsequently acquired at least seven sets of ATC equipment for the PLAAF's sole use, complicating the ATM problems CAAC now faces; additional CUA ATC system purchases are likely. See "Hughes Guardian Air Traffic Control System Operational in China", *Hughes Information Technology Systems (HITS)*, Richmond, British Columbia, Canada, 14 August 1997.

[21] The PLAAF trained at least 63 air traffic controllers, including 12 women, for civil duty with CAAC. See "Air Force Trains Air Traffic Controllers for Civilian Industry", *Xinhua New China News Agency*, 20 July 1989.

[22] This was another by-product of CAAC's reform. The State Council directive gave CAAC wide-ranging legislative and oversight authority in addressing general aviation (GA) issues. See "CAAC Takes Over All Responsibility for Civilian 'Flight Activities'", *Xinhua New China News Agency*, 15 January 1986.

[23] See Michael Mecham, "China Tackles Critical Aviation Safety Issues", *Aviation Week & Space Technology*, 2 October 1995, p. 50; "Chinese Daily Says Chronic Pilot Shortfall Plagues Air Safety", Air Safety Week, 21 February 1994; and "Civil Aviation Industry's Poaching of Air Force Pilots a 'Very Serious' Problem", *Xinhua New China News Agency*, 23 March 1994.

[24] See "'China sets up Air Traffic Control Bureau; Air Force Hands Over Power of Control", *Ming Pao* (Hong Kong), 6 February 1987. The bureau operated under the dual leadership of the State Council and the Central Military Commission. In 1987, a mid-air collision between a Chinese Boeing 737 and a PLAAF F-6 (MiG-19 Farmer) fighter reconfirmed the justification for the bureau's existence. See "Collision between an Airliner and a Fighter at Fuzhou Airport", *Xinhua New China News Agency*, 16 June 1987, and "CAAC's Airliner Collides with Fighter Plane", *Xinhua New China News Agency*, 16 June 1987.

over the ensuing years, for uncertain reasons, the PLAAF continued its hold over China's air space. In August 1994, the committee returned to CAAC subordination as the Air Traffic Management Bureau (ATMB),[25] and China created a new organization, the National Air Traffic Control Commission (NATCC), to address national air route issues. The NATCC now operates under the leadership of Vice-premier Zou Jiahua.[26]

In October 1994, the U.S. Department of Defense, under the leadership of Secretary William Perry, forged an ATC relationship with China's Commission on Science, Technology and Industry for National Defense (COSTIND), the principal initiative of the U.S.-China Joint Defense Conversion Commission (JDCC).[27] The JDCC, which Secretary Perry terminated under political pressure in 1996, promoted the civil-military collaboration on air space use, principally through a series of reciprocal visits between American and Chinese ATC and air space management experts. It also served as a key catalyst for continuing the discussion of ATM issues among the PLAAF, CAAC, COSTIND and the NATCC.

Measurement and Reporting of Civil Aviation Performance. CAAC measures and reports its civil aviation progress in a highly stylized, three-part manner. Early each year, it publishes the statistics of the previous year's performance, adding the coordinated goals for the civil air operations of the upcoming year. Typically, these statistics begin with new aircraft acquisitions and orders, including a list of new transports that entered civil service during the previous year (Boeing airliners and freighters; Airbus; McDonnell Douglas, and others, such as Yakolev or Learjet business aircraft). Second, CAAC uses three analytical categories to express its route and volume increases: total air transport volume, usually reported in terms of hundred million ton-kilometers or billion ton-kilometers; passenger volume, reported in terms of ten million passengers; and cargo carrying volume, reported in terms of 10,000 tons. Finally, CAAC summarizes China's air route structure by reporting the number of domestic, regional (Hong Kong) and international routes. On occasion, CAAC also summarizes China's aircraft and airport totals.[28]

Annual Statistical Summary. Selected samplings of China's annual civil air performance are provided on page 11; page 12 provides details on China's airline performance for 1994, a typical year of operation. As a result of CAAC's effort to separate government from business, which began in 1984, China today has six regional

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[25] ATMB, led by Director Chen Xuhua, exists today as CAAC's functional ATC/ATM authority.

[26] Vice-premier Zou became personally involved in investigating civil aviation matters following China's worst civil airliner accident, the crash of a China Northwest Airlines Russian-built TU-154M on 6 June 1994, which killed all 160 passengers and crew. See "China Airline Chief Announces Resignation over Crash", *Japan Economic Newswire*, 8 June 1994. This crash occurred on the same day that another Chinese airliner, a China Southern Airlines Boeing 737, was hijacked to Taiwan. See "Mainland Airliner Hijacked to Taiwan", *Central News Agency*, 6 June 1994.

[27] See Robert Butler and Rusty Shughart, "The Air Traffic Control (ATC) Initiative: A Case Study in U.S. Decision-making and U.S.-China Relations", *U.S. Air Force Institute for National Security Studies*, (forthcoming).

[28] These numbers are often much more impressive as aggregate totals than as individual sites or platforms. For example, CAAC's domestic fleet in 1980 reportedly consisted of about 30 1969-vintage turboprop aircraft in the 25-100-seat capacity range, and about 400 10-30-passenger piston-engine aircraft dating from the 1950's. See Robert R. Ropelewski, "China's Aerospace Market Eyed Warily", *Aviation Week and Space Technology*, 11 June 1979.

"backbone airlines"[29] and approximately 25 smaller commercial airlines.[30]

Trend of Growth and Expansion of Civil Air Operations. The consistent high degree of growth and expansion of China's civil air operations continues to strain the national ATM capacity. During the most-recently concluded five-year plan,[31] China's civil aviation performance ranked tenth in the world.[32] Compared with the execution statistics for 1990, the three key indicators of gross transport volume, passengers and cargo/mail increased 178 percent, 201 percent and 165 percent, respectively.[33] Over the five-year term, China's commercial air fleet grew to 416 aircraft, largely through lease arrangements[34] or outright purchase.[35] The nation's 680 domestic air routes linked 134 cities, while its 87 international routes connected China with 56 cities in 39 countries around the globe.[36] The trend continues through 1998.[37]

Future Growth and Expansion of Civil Air Operations. CAAC predicts that China will continue to grow and expand its civil air operations well into the 21st Century.[38] CAAC has designed the civil air fleet and ATM initiatives of the ninth five-year plan (1996-2000) to position China to attain world-class status in civil aviation by 2015. By then, China hopes to open 30 additional international airports, largely through the assistance of international investment and financial support; China will need to procure nearly 1,300 additional airliners between 1995-2014.[39]

CAAC also hopes to extend the scope of China's civil aviation to a truly global operation; Latin America, where China does not yet operate scheduled air services, is the logical next venue for CAAC expansion. In 1994, CAAC Minister Chen Guangyi and the Brazil Minister of the Air Force signed an air service agreement in Beijing on behalf of the two governments. The accord was China's first with a Latin American country and began the process of negotiation on opening official air routes.[40] In mid-1996, Chen led a CAAC delegation on a two-week goodwill mission to South America, including a follow-

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[29] The six backbone airlines and their headquarters are Air China/Beijing, China Southern Airlines/Guangzhou (Canton), China Eastern Airlines/Shanghai, China Southwest Airlines/Chengdu, China Northern Airlines/Shenyang and China Northwest Airlines/Xi'an.

[30] Air China leads the way as China's principal international flag carrier airline. Interestingly, the literal translation of Air China is "China International Airlines" (zhongguo guoji hangkong gongsi); the Chinese have likely selected 'Air China' as its registered translated rendering in lieu of referring to their international flag carrier by the acronym "CIA."

[31] China's manages its centrally-planned economy in terms of five-year cycles. The eighth five-year plan covers the years 1991-1995; the ninth five-year plan covers the years 1996-2000.

[32] See "Civil Air Transport Booming in China", *Xinhua New China News Agency*, 17 November 1995.

[33] *Ibid.*

[34] China reportedly leased 194 airliners during the eighth five-year plan. *Ibid.*

[35] The China Aircraft Supplies Corporation (CASC) is China's purchasing agent for new aircraft acquisition.

[36] *Ibid.*

[37] CAAC's estimates that in 1998, China's civil air operation will extend to 62 cities around the world; CAAC's passenger volume goal for 1998 is 61 million. See "Major Expansion for Civil Aviation Sector", *China Daily*, 26 March 1998.

[38] In late-1995, CAAC Deputy Director General Shen Yuankang described China's long range civil aviation plan during a press conference announcing China's Zhuhai '96 Aerospace and Aviation Fair (Zhuhai is one of China's five SEZ's). See "China to Add 1,300 Passenger Aircraft over the Next 20 Years", *Xinhua New China News Agency*, 1 December 1995, and "China's Domestic Air Traffic to Double by 2000", *Xinhua New China News Agency*, 1 December 1995.

[39] *Ibid.*

[40] See "Qian Qichen Receives Brazilian Minister after Signing of Air Service Agreement", *Xinhua New China News Agency*, 11 July 1994. Qian was China's foreign minister at that time.

China's Civil Aviation Performance Statistics

Selected Years

Calendar Year	Total Routes	International Routes	Domestic/ Regional Routes	Total Ton-Kilometers	Passenger Volume	Cargo Volume (Tons)	Civil Aircraft	Civil Airports
1976	131	09	118/4	18.7 million	01.46 million	53.91 million	494	060
1980	181	18	159/4	467 million	03.70 million	100 million	462	----
1987	325	39	280/6	2.03 billion	13.10 million	195 million	460	----
1988	332	----	----	2.25 billion	13.71 million	320 million	----	084
1989	350	38	308/4	1.99 billion	12.05 million	300 million	----	093
1990	370	45	321/4	3.19 billion	24.87 million	593 million	323	100
1993	616	60	550/6	5.20 billion	34.80 million	694 million	373	113
1994	727	84	630/13	5.84 billion	40.39 million	830 million	----	132
1995	----	----	680	7.14 billion	51.23 million	1.01 billion	416	140
1997	----	106	----	8.67 billion	56.30 million	1.25 billion	490	142
1998 (est.)	----	124	----	9.50 billion	61.0 million	1.38 billion	----	----

Primary Information Sources:

"Major Expansion for Civil Aviation Sector", *China Daily*, 26 March 1998
"China's Airline Industry Made Progress in All Aspects", *International Aviation*, February 1996, p. 1.
"China's Airline Industry has Sustained High Growth Rate; State Set to Launch Air Safety Crackdown", *International Aviation*, February 1994, p. 1.
"CAAC Continues to March Forward", *International Aviation*, April 1990, p. 8.
China Today: Civil Aviation Industry; 1989.

China's Civil Aviation Performance Statistics

Detailed Summary of 1994

Total Execution	1994	Comparison with 1993
Total Ton-Kilometers	5.84 billion	increase of 14.1 percent
Domestic	3.77 billion	increase of 20.8 percent
International	1.70 billion	increase of 7.1 percent
Regional	0.37 billion	decrease of 9.8 percent

Top 10 Airline Performance

(Total ton-kilometers)	
Air China	1.64 billion
China Southern Airlines	1.00 billion
China Eastern Airlines	894 million
China Southwest Airlines	533 million
China Northern Airlines	483 million
China Northwest Airlines	242 million
Xinjiang Airlines	230 million
Xiamen Airlines	191 million
Yunnan Airlines	145 million
Shanghai Airlines	117 million
All Others (combined)	353 million

On-time Regularity of Scheduled Flight Operations

	Total	Domestic	Intl/Domestic
Air China	81.6 percent	84.9 percent	71.8 percent
China Eastern Airlines	86.4 percent	88.1 percent	82.5percent
China Southern Airlines	81.6 percent	81.5 percent	82.4 percent
China Southwest Airlines	87.7 percent	87.5 percent	91.2 percent
China Northwest Airlines	81.0 percent	80.7 percent	87.0 percent
China Northern Airlines	86.6 percent	86.6 percent	85.5 percent
Xinjiang Airlines	86.2 percent	86.8 percent	69.5 percent
Xiamen Airlines	85.3 percent	85.9 percent	72.1 percent
Yunnan Airlines	92.1 percent	92.0 percent	93.6 percent
Shanghai Airlines	82.1 percent	82.1 percent	not reported

Passenger Load	1994	Comparison with 1993
Average (all)	69.0 percent	decrease of 2.8 percent
Domestic Routes	73.5 percent	decrease of 3.1 percent
International Routes	57.3 percent	decrease of 0.2 percent
Regional Routes	56.0 percent	decrease of 12.9 percent

Aircraft Use	1994	Comparison with 1993
Average (all)	4.8 hours daily	decrease of 0.1 hours
Large airliners	5.7 hours daily	decrease of 0.3 hours
Small Airliners	2.1 hours daily	not reported

Source: "1994 Statistic Report on China's Airlines", *International Aviation*, May 1995, p. 23.

up visit to Brazil.[41] The visit is another indication that CAAC is laying the foundation for China to operate air services throughout the region in the future.

The unknowns of the Asian economic crisis notwithstanding, state economic and political pressures to continue to grow and expand China's air routes and scheduled flight operations will likely continue into the foreseeable future. What is less clear is the degree to which the military and national political factors will support or hinder this development. These variables depend greatly on the past and future developments of civil air safety and security.

China's Air Safety and Security Record. Over the past 30 years, China has had an unstable civil aviation safety and security record. Generally, the underlying reasons for this inconsistency are manifold, attributable to the complexities and prioritization of developing a decentralized, modern jet transport industry in an extremely short period of time.[42] The tables on pages 15-18 summarize China's modern aviation safety and security record, to include commercial flight hijackings and military air defection incidents, both to and from Taiwan.[43]

Air Safety. It is impossible to determine from open source reporting exactly how many civil air accidents in China can be attributed to the shortcomings of the nation's ATM system.[44] However, it is clear that following a steady increase in air safety breeches leading up to the current decade, the long series of civil air accidents from July 1992 to June 1994 comprise the most tragic era of China's modern civil aviation history. At least 11 Chinese airliners and helicopters were involved in severe safety incidents during this period, killing more than 540 people; among these incidents were three airliner crashes that each claimed the lives of 100 or more passengers and crew.

Of equal concern is the unknown number of "near-miss" incidents in the skies over China. Such occurrences, rarely reported in the open media, are a direct reflection of national ATM shortcomings, particularly among flights operating in inclement weather, along high-density air routes or under other difficult circumstances.[45] In 1995,

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[41] From 27 May to 9 June, the group visited Brazil, Argentina, Chile and Peru to "promote friendly relations of cooperation" and to discuss the "possibilities of direct aviation exchanges." See "CAAC Delegation Leaves for Visit to Four Latin American Countries", *Xinhua New China News Agency*, 25 May 1996.

[42] The International Air Transport Association (IATA) cites the break-up of former monopoly state airlines in China and Russia as a primary factor for the poor civil air safety performance of these nations. See Robert Evans, "China Airline Break-ups Hit Safety – IATA", *Reuter's World Service*, 15 June 1994. IATA noted that both Russia and China had begun to provide IATA with accident statistics after decades of guarding such information as secret. IATA was equally concerned with civil aviation in Russia, where 348 people were killed in civil air accidents in 1993, compared with 250 in 1992.

[43] The information on these tables was collected by the author from open source reporting, Chinese and otherwise. China's true safety and security record is unknown, due largely to concerns of state secrecy and national security. For example, China does not report details on its military air accidents, and until the mid-1980's did not report its civil air accidents unless they involved the death of Westerners. See "China's Secretive Aviation Authority Reveals More Plane Crashes", *Reuters Library Report*, 21 January 1989; Janet Snyder, "Chinese Media Mute Coverage of Worst Air Disaster in Decade", *Reuter Library Report*; "Chinese Refuse to Release List of Injured after Plane Crash", *Reuters*, 4 October 1990; and Mary Kwang, "Problems, Problems and More Problems for Mainland Airlines, *The Straits Times*, 8 June 1994, p. 4.

[44] China's air safety record is undoubtedly much worse than the public record indicates, although there have been some surprisingly high unofficial accounts. See "China Plane Crashes Killed 2,000 Last Year", *The Reuter Library Report*, 14 May 1990. This report cites a *Literary Digest* claim that over 2,000 people died in 70 plane crashes across China in 1989, the nation's worst single year for aviation deaths. The article adds that the crashes, occurring at a rate of about one every five days, mostly involved military aircraft.

[45] There have been unofficial, unconfirmed accounts of "near-miss" incidents in China. In 1990, Western passengers on a flight from Kunming reported a near-collision with an unidentified China Southern Airlines airliner as they were about to land in Beijing. One

ATMB Director Chen Xuhua, speaking informally during an interview with aviation reporters, noted that "about 10 near-miss mid-air conflicts occurred [in 1994] because of insufficient ATC and controller carelessness."[46] Chen added that these incidents demonstrate the need to improve China's ATC infrastructure.[47]

Near and on the ground, the ATM challenge is equally daunting. In the 1980's, prior to the construction of a sufficient network of civil airports, CAAC relied on dual-use airfields, sharing runways and ATM services with the PLAAF. Collisions between commercial and military aircraft on and near the runway surface reflect the danger and risk of combined airport operations. A collision between a Chinese Hawker-Siddeley Trident jetliner and a PLAAF F-6 (MiG-19 Farmer) fighter jet at Guilin[48] in 1983 – the first official acknowledgement of airport dual use operation – killed 10 people and injured 21.[49] In 1987, a CAAC Boeing 737 was involved in a mid-air collision with another PLAAF F-6 over the runway at Fuzhou, killing the fighter pilot and injuring one passenger.[50] More recently, surface accidents[51] have occurred at independent (non-"dual use") civil airports. Recent examples include the crash in 1997 of a China Southern Airlines Boeing 737 at Shenzhen, killing 35;[52] a runway overrun of a China Northern Airlines MD-82 at Dalian in 1997;[53] and the crash into a mountainside of a China Flying Dragon Airlines Yun-12 transport in Shandong in 1996, killing two.[54]

Officially, CAAC's Aviation Safety Office oversees China's civil air safety programs and initiatives.[55] In a recent interview, its deputy director, Ban Yongkuan, stated that China's civil aviation industry had 121 safety incidents in 1995, compared to 133 in 1994.[56] Ban added that ATC[57] accounted for about seven percent of the incidents over the two-year period, with the bulk of the remainder attributed to aircraft mechanical problems (41 percent) or the air crew (35 percent).[58] Aside from Ban's perspective, other Chinese organizations have contributed to the analysis of China's air safety challenge. In 1997, the Aviation Safety Science Institute of China's Civil Aviation College published

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passenger reported the distance between the two aircraft as within 50 meters. See "CAAC Planes Reported Narrowly Miss Collision over Beijing", *The Reuter Library Report*, 20 February 1990.

[46] See Wei Shijie and Zhang Ting, "Unimpeded Routes in the Blue Sky – An Interview with ATMB Director Chen Xuhua", *International Aviation*, May 1995, p. 28.

[47] *Ibid.*

[48] Guilin is a famous tourist center in south-central China, popular because of the scenic beauty of the rugged limestone mountains throughout the region. It has also been the site of numerous civil air incidents and accidents, primarily due to inclement weather, high air traffic density and difficult ATC conditions.

[49] See "CAAC Trident, Military Aircraft Collide in Guilin", *Xinhua New China News Agency*, 14 September 1983.

[50] See "Collision between an Airliner and a Fighter at Fuzhou Airport", *Xinhua New China News Agency*, 16 June 1987.

[51] Generally, many of these accidents can be categorized as "controlled flight into terrain," or CFIT.

[52] See Renee Lai, "Southern Airlines to Cut Back", *South China Morning Post*, 3 April 1988, p. 3.

[53] See "Airline Safety Review", *Flight International*, 21 January 1998.

[54] See "Pilot Error Causes Plane Crash", *Xinhua New China News Agency*, 28 June 1996.

[55] The Air Safety Office reports directly to Wang Li'an, the former president of China Eastern Airlines (Shanghai) and one of four CAAC vice ministers. Wang also oversees other CAAC air safety and security programs, including airworthiness, civil air defense liaison and public security. See "The General Administration of Civil Aviation of China" (CAAC organization chart), *Sino Aviation News*, May 1997.

[56] See Zhang Ting, "1995, the Year of Airline Safety in China – Visiting with Mr. Ban, an Official of the Aviation Safety Office in CAAC", *International Aviation*, March 1996, pp. 24-27. Mr. Ban is now retired.

[57] Includes civilian and military ATC.

[58] *Ibid.* An "incident" presumably includes fatal and non-fatal equipment destruction (accidents) and violations of operational flight regulations. CAAC has not published its criteria for classifying the reasons for air safety incidents. In addition to the analytical categories of maintenance, air crew and ATC, Ban noted that other major safety groupings included weather, ground security and miscellaneous factors.

Aviation Safety in China (1968 – 1998)

Date	*Incident Type*	*Country Involved*	*Aircraft Involved*	*Description of Incident*
10 Sep 98	CAA	PRC	MD-11	Emergency landing at Shanghai (Hongqiao); landing gear malfunction; Shanghai-Beijing; 1 injured; China Eastern Airlines
20 Jul 97	CAA	PRC	MD-82	Crash at Dalian; overrun of runway upon take-off; no one injured; China Northern Airlines
09 May 97	CAA	PRC	Boeing 737	Crash at Shenzhen; 35 killed, 35 injured; Chongqing-Shenzhen; China Southern Airlines
27 Apr 97	CAA	PRC	MD-82	Crash landing at Jinan; right main landing gear collapses; no one injured; China Eastern Airlines
21 Jun 96	CAA	PRC	Yun-12 Mk2	Crash in Changai, Shandong; 2 killed (3 crew, 9 passengers); China Flying Dragon Airlines
20 July 94	CAA	PRC	Boeing 737-300	Crash while landing at Kunming; no one killed
06 Jun 94	CAA	PRC	Tupolev TU-154M	Crash at Xi'an; 160 killed; China Northwest Airlines; * China's worst aviation accident
13 Nov 93	CAA	PRC	MD-82 (DC-9)	Crash at Urumqi; 12 killed, 60 injured; Beijing-Urumqi; China Northern Airlines
26 Oct 93	CAA	PRC	MD-82 (DC-9)	Crash at Fuzhou; 2 killed, 13 injured; Qilu Company, Ltd (China Eastern Airlines subsidiary)
23 Jul 93	CAA	PRC	BAe-146	Crash at Yinchuan, Ningxia; Yinchuan-Beijing; 59 killed; China Northwest Airlines
06 Apr 93	CAA	PRC-US	MD-11	Emergency landing in the Aleutian Islands; 2 killed, 160 injured
24 Nov 92	CAA	PRC	Boeing 737-300	Crash at Guilin; 141 killed; China Southern Airlines
05 Nov 92	CAA	PRC	Mi-17 helicopter	Crash in Henan; 33 killed, 46 injured; crash occurs while dropping advertising leaflets near shopping center; civilian use of military helicopter
08 Oct 92	CAA	PRC	Ilyushin IL-14 turboprop	Crash in Lanzhou; Gansu-Xi'an; 14 killed, 21 injured; Wuhan Airlines
21 Aug 92	CAA	PRC-Hong Kong	Boeing 747	Accident at Kai Tak International (smoke coming from engine prior to take-off); 280 people evacuated (no one injured); Air China
11 Aug 92	CAA	PRC	Mi-8 helicopter	Crash in Beijing; 15 killed (most Japanese); China Great Wall Airlines; crash occurs during scenic tour of the Great Wall
31 Jul 92	CAA	PRC	Yakolev YAK-42 jetliner	Crash in Nanjing; 106 killed, 20 injured; China General Airline Company
21 May 91	CAA	PRC	Boeing 737	Crash at Xiamen; no one injured; Kunming-Xiamen; China Southwest Airways; airport closed after aircraft strikes runway lights
25 Apr 91	CAA	PRC	Boeing 757	Crash at Kunming; 2 injured
02 Oct 90	CAA/CAH	PRC	Boeing 737	Hijack/Crash at Guangzhou; Xiamen-Guangzhou; 127 killed, 53 injured; Xiamen Airlines; Boeing 707-320B and Boeing 757 also destroyed in collisions landing at Baiyun International Airport; * on-board struggle is part of China's most sensational aviation accident (Jiang Xiaofeng)
22 Jun 90	CAA	PRC-Hong Kong	Boeing 747	Emergency landing at Kai Tak International; 3 injured; Singapore-Hong Kong
22 Mar 90	CAA	PRC	Hawker-Siddeley Trident (DH-121)	Crash during landing at Guilin; no one killed; Air China
15 Aug 89	CAA	PRC	Antonov AN-24 turboprop	Crash at Shanghai; 18 killed; Shanghai-Nanchang (China Eastern Airlines or Jiangxi Regional Administrative Bureau aircraft)
07 Oct 88	CAA	PRC	Ilyushin IL-14 turboprop	Crash at Linfen, Shanxi; 42 killed; Shanxi Provincial Aviation Company; "pleasure flight" as reward for model workers
31 Aug 88	CAA	PRC-Hong Kong	Hawker-Siddeley Trident (DH-121)	Crash at Kai Tak International; 7 killed; CAAC; * worst airline crash in Hong Kong in 20 years
Jul 88	CAA	PRC	Tupolev TU-154	Crash at Jinjiang, Hebei; no one injured
Jun 88	CAA	PRC	Yun-5	Crash in Hunan; 8 killed
18 Jan 88	CAA	PRC	Ilyushin IL-18 turboprop	Crash in Chongqing; 108 killed; China Southwest Airlines; engine failure; * first crash of newly-independent airline aircraft
16 Jun 87	CAA	PRC	Boeing 737/MiG-19	Crash in Fuzhou; 1 killed, 1 injured * first reported airborne collision in China
15 Dec 86	CAA	PRC	Antonov AN-24 turboprop	Crash in Lanzhou; 6 killed
18 Jan 85	CAA	PRC	Antonov AN-24 turboprop	Crash in Jinan, Shandong
14 Sep 83	CAA/MAA	PRC	Hawker-Siddeley Trident/MiG-19	Crash at Guilin; 10 killed, 21 injured * first reported crash between civil and military aircraft
04 Apr 83	CAA	PRC	King Air 200 helicopter	Crash at Guangzhou
24 Dec 82	CAA	PRC	Ilyushin IL-18 turboprop	Crash at Guangzhou; 34 killed, 20 injured; Lanzhou Regional Administrative Bureau
17 Sep 82	CAA	Japan-PRC	DC-8	Crash at Shanghai; 39 injured; Japan Air Lines; mechanical problem and hydraulic brake failure

26 Apr 82	CAA	PRC	Hawker-Siddeley Trident (DH-121)	Crash in Guilin; 112 killed (54 Hong Kong Chinese; 2 Americans); possible PLAAF pilot; * first acknowledged crash of CAAC jetliner
21 Apr 81	CAA	PRC	BO-105 helicopter	Crash in Beijing
20 Mar 80	CAA	PRC	Antonov AN-24 turboprop	Crash in Changsha, Hunan
27 Feb 77	CAA	PRC	Ilyushin IL-18 turboprop	Crash in Shenyang
21 Jan 76	CAA	PRC	Antonov AN-24 turboprop	Crash in Changsha; 34 killed, 10 injured; Guangzhou Regional Administrative Bureau
14 Jan 73	CAA	PRC	Ilyushin IL-14 turboprop	Crash in Guiyang; Chengdu Regional Administrative Bureau
13 Sep 71	CAA/CAH	PRC	unspecified helicopter	Hijack/Crash, Huaizhou County, north of Beijing; Chen Xiuwen, prevents hijacking by Lin Biao clique of helicopter to Ulan Bator, Mongolia; Central Military Commission later awarded Chen PLA "loyal fighter" status; Chen is shot and killed in hijack attempt
14 Nov 70	CAA	PRC	Ilyushin IL-14 turboprop	Crash at Guiyang; Guangzhou Regional Administrative Bureau
05 Dec 68	CAA	PRC	Ilyushin IL-14 turboprop	Crash at Beijing; unspecified number killed

Abbreviations:

Aircraft Shootdown (AS)	Civil Air Defection (CAD)	Civil Air Hijacking (CAH)
Civil Air Accident (CAA)	Military Air Accident (MAA)	Military Air Defection (MAD)

Note: All items of this list were compiled by the author from open source reporting.

Aviation Security in China (1968 – 1998)

Date	*Incident Type*	*Country Involved*	*Aircraft Involved*	*Description of Incident*
10 Mar 97	CAH	Taiwan-PRC	Boeing 757-200	Hijack, Kaohsiung-Taipei; diverts to Xiamen; Far Eastern Air Transport (Liu Shanzhong [Liu Shan-chung]); * first hijack of civil airliner from Taiwan to China; hijacker is retired lieutenant colonel (1985), Taiwan Army counterintelligence; four CNAF F-5 fighters scrambled but did not pursue passenger jet as it left Taiwan airspace
10 Feb 97	CAH	PRC	unspecified	Hijack attempt, aircraft diverts to Guangzhou; Wuhan-Chongqing-Zhuhai; China Northwest Airlines; crew overpowers sole hijacker
16 Nov 96	CAH	PRC	unspecified	Hijack attempt, Guangzhou-Xiamen; Xiamen Airlines
10 Mar 96	CAH	PRC	Boeing 737	Hijack attempt, Guangzhou-Haikou; lands at Zhuhai following demands to divert to Taiwan; Hainan Airlines; * incident occurs during PLA multi-service wargames off south China coast
02 Aug 95	CAH	PRC	unspecified	Hijack attempt, Shanghai-Guangzhou; China Eastern Airlines
10 Mar 95	CAA	PRC	Boeing 737	Hijack attempt, Zhejiang-Guangzhou, Hainan Airlines; hijacker reportedly took woman passenger at knifepoint, overpowered by passengers and crew (Jin Xiaoping)
23 Dec 94	CAH	PRC	Yakolev YAK-42	Hijack attempt, Xiamen-Nanjing; attempt to divert to Taiwan; China General Aviation Corporation
06 Jun 94	CAH	PRC-Taiwan	Boeing 737	Hijack, Fuzhou to Guangzhou; diverts to CKS International; China Southern Airlines (Zhou Weiqiang)
18 Feb 94	CAH	PRC-Taiwan	Boeing 737	Hijack, Chengdu-Fuzhou; diverts to CKS International; China Southwest Airlines (Lin Wenqiang, his wife [Wang Chunming], two children and foster mother)
29 Dec 93	CAH	PRC	unknown	Hijack attempt, unknown China origin to New York
28 Dec 93	CAH	PRC-Taiwan	Yun-7 turboprop	Hijack, Ganzhou (Jiangxi)-Xiamen; diverts to CKS International; Fujian Airlines (Luo Changhua, Wang Yuying [wife], 8-year-old son [Wanghuan])
12 Dec 93	CAH	PRC-Taiwan	Boeing 737-200	Hijack, Harbin-Xiamen; diverts to CKS International, Taiwan; Xiamen Airlines (Qi Daquan)
08 Dec 93	CAH	PRC-Taiwan	MD-82 (DC-9)	Hijack, Qingdao-Fujian; diverts to Taiwan; China Northern Airlines (Gao Jun, girlfriend [Jiang Shumei]); this aircraft also hijacked to Taiwan on 12 Nov 93; * CNAF reports PLAAF scrambled 4 unspecified MiG fighters in pursuit
26 Nov 93	CAH	PRC-Taiwan	Fokker 100	Hijack attempt, Nanjing-Fuzhou; aircraft lands in China (unspecified) after on-board struggle; China Eastern Airlines (Gao Guangkai)
12 Nov 93	CAH	PRC-Taiwan	MD-82 (DC-9)	Hijack, Changchun-Fuzhou; diverts to CKS International; China Northern Airlines (Han Shuxue, Li Xiangyu); this aircraft also hijacked to Taiwan on 8 Dec 93
08 Nov 93	CAH	PRC-Taiwan	Dash 8-301 turboprop	Hijack, Hangzhou-Fuzhou; diverts to CKS International; Zhejiang Airlines (Wang Zhihua)
05 Nov 93	CAH	PRC-Taiwan	Boeing 737	Hijack, Guangzhou-Xiamen; diverts to CKS International; Xiamen Airlines (Zhang Hai)
30 Sep 93	CAH	PRC-Taiwan	Tupolev TU-154	Hijack, Jinan-Guangzhou; diverts to CKS International; Sichuan Airlines (Yang Mingde, Han Fengying [wife], 6-year-old son
10 Aug 93	CAH	PRC-Taiwan	Boeing 767-200	Hijack, Xiamen-Jakarta; diverts to CKS International; Air China (Shi Yuebo)
24 Jun 93	CAH	PRC-Taiwan	Boeing 737	Hijack, Changzhou-Xiamen; diverts to CKS International; Xiamen Airlines; (Zhang Wenlong, PLA soldier)
06 Apr 93	CAH	PRC-Taiwan	Boeing 757	Hijack, Shenzhen-Beijing; diverts to CKS International; China Southern Airlines; (Liu Baocai, Huang Shugang)
02 Oct 90	CAH/CAA	PRC	Boeing 737	Hijack/Crash at Guangzhou; Xiamen-Guangzhou; 127 killed, 53 injured; Xiamen Airlines; Boeing 707-320B and Boeing 757 also destroyed in collisions landing at Baiyun International Airport; * on-board struggle is part of China's most sensational aviation accident (Jiang Xiaofeng)
16 Dec 89	CAH	PRC-Japan	Boeing 747	Hijack, Shanghai-San Francisco; lands in Fukuoka after refusal to divert to South Korea; Air China; * first successful hijacking of a CAAC international flight (Zhang Zhenhai, wife and 10-year-old son); Zhang extradited to China, sentenced to 8-year prison term
06 Sep 89	MAD	PRC-Taiwan	MiG-19	Defection; Jiang Wenhao, PLAAF MiG-19 (F-6) to Quemoy, Taiwan
24 Apr 89	CAH	PRC	unspecified	Hijack attempt, Ningbo-Xiamen; lands in Fuzhou after refusal to divert to Keelung; 1 killed (hijacker), 2 injured; hijacker detonates hand grenade (Liang Aozhen); CAAC awards crew for heroism
11 Feb 89	MAD	Taiwan-PRC	F-5E	Defection (Lt Col Lin Hsien-shun ([Xianshun]): ejects from fighter which crashes in Fengshun County, Guangdong Province (150 miles north of Guangzhou); * pilot reportedly carried classified documents
12 May 88	CAH	PRC	Boeing 737-200	Hijack, Xiamen-Guangzhou; diverts to Chingchuankang Airbase, Taichung; * first direct hijack of a CAAC airliner to Taiwan (Jiang Qingguo, Long Guiyun)
05 Oct 87	AS	PRC-Vietnam	MiG-21 Fishbed	Shootdown, PLAAF shootdown of Vietnamese MiG-21 Fishbed fighter jet after it intrudes 20 miles into Chinese airspace, Guangxi

19 Jul 87	MAD	PRC-Taiwan	MiG-19	Defection; Liu Zhiyuan, PLAAF MiG-19 (F-6) to Taichung, Taiwan
24 Oct 86	MAD	PRC-South Korea	MiG-19	Defection; Zheng Caitian, PLAAF MiG-19 (F-6) to South Korea
03 May 86	CAD	Taiwan-PRC	Boeing 747 (freighter)	Hijack, Bangkok-Taipei; Diverts to Guangzhou; China Airlines Boeing 747; China gives pilot political asylum; * first incident of Taiwan commercial aircraft hijacked to China; * incident leads to the first China-Taiwan negotiations in 37 years, a major political breakthrough (Wang Xijue [Wang Hsi-chueh])
21 Feb 86	MAD	PRC-South Korea	MiG-19	Defection; Zhen Baozhong, PLAAF MiG-19 (F-6) to South Korea (Shenyang-Suwon)
19 Dec 85	CAH	USSR-PRC	Antonov AN-24 turboprop	Hijack to Qiqihar, Heilongjiang; Aeroflot (Captain Alimuradov Shamil Gadji Ogly)
24 Aug 85	MAD	PRC-South Korea	Ilyushin IL-28 (H-5) jet bomber	Defection; Xiao Tianyan, PLANAF H-5 (IL-28) to South Korea; navigator killed in crash landing; radioman later returns to China
22 Jun 84	CAH	PRC	Hawker-Siddeley Trident (DH-121)	Hijack attempt, Nanchang-Fuzhou; crew reportedly overpowers sole hijacker
22 Mar 84	CAH	UK-PRC-Taiwan	Boeing 747	Hijack, British Airways; diverts to CKS International; * first hijacking of an international commercial flight in Chinese airspace (Liang Weiqiang)
14 Nov 83	MAD	PRC-Taiwan	MiG-17	Defection; Wang Xuecheng, PLANAF MiG-17 (F-5) to CKS International, Taiwan; based at Daishan, Zhoushan Islands
02 Nov 83	AS	PRC	unspecified	Shootdown; PLAAF fighter fires on PLAAF aircraft thought to be defecting; emergency landing; no one injured; (Captain Jin Luojun and co-pilot Shangguan Yuhong)
14 Sep 83	CAA/MAA	PRC	Hawker-Siddeley Trident/MiG-19	Crash at Guilin; 10 killed, 21 injured * first reported crash between civil and military aircraft
07 Aug 83	MAD	PRC-South Korea	MiG-21	Defection; Sun Tianqin (test pilot); PLAAF MiG-21 to South Korea (NKAF Chinese-made MiG-21); * China's most significant military air intelligence loss by defection
27 May 83	MAD	PRC	MiG-19	He Guoli (Ho Kuo-li); reportedly shot and killed in attempt to defect to Taiwan; aircraft is forced down by two PLAAF MiG-19's
05 May 83	CAH	PRC-South Korea	Hawker-Siddeley Trident (DH-121)	Hijack, Shenyang-Shanghai; diverts to South Korea after North Korea refuses permission to land; 2 killed; first successful hijacking of a CAAC airliner to location outside China; * incident brings Chinese representatives to South Korea for the first time, a major diplomatic breakthrough; * first woman hijacker in China (Zhuo Changren, Jiang Hongjun, Wang Yanda, An Weijian, Wu Yunfei, Gao Dongping)
22 Apr 83	MAD	Taiwan-PRC	U-6A turboprop	Defection; Li Dawei, CNAF U-6A turboprop observation craft to China (Hualien-Fujian)
Feb 83	CAH	PRC	Ilyushin IL-14 turboprop	Hijack attempt, Hangzhou-unspecified; lands in Shanghai following demand to divert to Taiwan; 2 killed; CAAC; * first reported on-board killing resulting from hijack attempt
Feb 83	MAD	DPRK-ROK-PRC	MiG-19	Defection; unnamed pilot; North Korean Air Force Chinese-made MiG-19 defects to South Korea
16 Oct 82	MAD	PRC-South Korea	MiG-19	Defection; Wu Ronggen, PLAAF MiG-19 to South Korea; based in Jinjiang, Fujian
25 Jul 82	CAH	PRC	Ilyushin IL-18 turboprop	Hijack attempt, Xi'an-Shanghai; attempt to divert to Taiwan; CAAC; * China's first acknowledged hijacking attempt; 5 hijackers later executed in public (Sun Yunping, Yang Feng, Gao Keli, Xie Zhimin, Wei Xueli); CAAC recognizes the aircrew's bravery with merit certificates and monetary bonuses
30 Sep 81	MAD	Vietnam-PRC	UH-1H helicopter	Defection; 10 Vietnamese defect to Guangxi in US-made helicopter
08 Aug 81	MAD	Taiwan-PRC	Northrop F-5F	Defection; Huang Zhicheng, CNAF F-5F (reconnaissance) to China (Taoyuan-Fuzhou); * Taiwan's most significant military air intelligence loss by defection
15 Apr 79	MAA	PRC-Vietnam	MiG-19	Crash near Nam Dinh, Vietnam (20 miles southeast of Hanoi); pilot killed; PLAAF jet aircraft
14 Mar 79	MAA	PRC	Hawker-Siddeley Trident (DH-121)	Crash into a factory of a Beijing suburb; 44 casualties (officially) (witnesses report as many as 200 killed); possible PLAAF pilot or mechanic; * some reports indicate pilot was attempting to crash into PLAAF headquarters; incident occurs during China's border hostilities with Vietnam
07 Jul 77	MAD	PRC-Taiwan	MiG-19	Defection; Fan Yanyuan, (Sqdn CC, Jinjiang airbase, Fujian); PLAAF MiG-19 to Taiwan
16 Jun 77	CAH	PRC	unspecified	Hijack attempt in Urumqi
14 Mar 74	MAA	USSR-PRC	Mi-4 helicopter	PLA "captures" Soviet helicopter and crew of three in Xinjiang, near China's nuclear weapons test facility at Lop Nor in likely reconnaissance mission; crew is released on 27 Dec 75, status of helicopter unreported
19 Sep 71	AS	PRC-Mongolia	Hawker-Siddeley Trident (DH-121)	Shootdown; PLAAF shootdown of Lin Biao group reportedly fleeing to USSR following coup attempt
13 Sep 71	CAH/CAA	PRC	unspecified helicopter	Hijack/Crash, Huaizhou County, north of Beijing; Chen Xiuwen, prevents hijacking by Lin Biao clique of helicopter to Ulan Bator, Mongolia; Central Military Commission later awarded Chen PLA "loyal fighter" status; Chen is shot and killed in hijack attempt
30 Mar 71	CAH	Philippines-PRC	BAC-111-400	Hijack, Manila to Guangzhou; Philippine Airlines; * first reported hijacking to China

Abbreviations:

Aircraft Shootdown (AS)	Civil Air Defection (CAD)	Civil Air Hijacking (CAH)
Civil Air Accident (CAA)	Military Air Accident (MAA)	Military Air Defection (MAD)

its findings of a study of national civil air safety data from 1980-94.[59] The report cited 80 civil aviation accidents (accidents, as opposed to incidents) during the 15 year period, analyzing the underlying reasons as generally falling into 12 subcategories under the larger headings of man, machine and environment.[60] Although the report did not specifically cite the degree of ATM involvement in the accident rate, it noted that the vast majority of civil aviation incidents and accidents in China, as in other parts of the world, resulted from the complex interaction of multiple factors.[61]

Air Security. In addition to addressing China's civil air safety concerns, CAAC also engages in significant initiatives and programs related to civil aviation security. Paramount among these concerns are responsibilities related to air hijacking incidents and military aircraft defections, both to and from Taiwan. From the PLAAF perspective, a major reason for not relinquishing greater amounts of air space, air routes and ATM authority to China's civil aviation sector is the inherent military concern for national defense and air sovereignty. The civil air security record reflects this insecurity, affirming the military's predominant role as China's aviation guarantor and protectorate.

Air Hijacking Incidents. China's first acknowledgement of a CAAC airliner hijacking occurred on 5 May 1983, with the commandeering of a Trident jetliner to South Korea.[62] During a scheduled flight from Shenyang to Shanghai, a group of six hijackers fired at least eight shots to force their way into the cockpit, wounding the navigator and radio operator. The hijacked airliner was forced to enter North Korean air space, where it was reportedly refused permission to land in Pyongyang. It subsequently diverted to a military airfield in South Korea,[63] where its arrival touched off a series of highly unusual and significant political events between China and South Korea, which did not have diplomatic relations.[64]

On 7 May, Shen Tu, CAAC Director General and a member of the Chinese Central Committee, led a 33-member delegation to Seoul to negotiate the release of the aircraft, crew and passengers. The visit was the first direct contact between Chinese and South Korean government organizations. In three days of negotiations, Shen failed to gain the release of the hijackers from South Korean authorities.[65] Following their trial in August, the hijackers were sentenced to prison terms of between four and six years; in 1984, their sentences were commuted and they were permitted to emigrate to Taiwan.[66]

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[59] See "China's Airlines Safety Evaluation System", *International Aviation*, March 1997, pp. 30-32.
[60] *Ibid.*
[61] *Ibid.* The report cited an unspecified study of 232 civil air accidents that occurred around the world from 1982-91, noting that "multiple factors" – forming a "chain of events" – were the underlying cause of 92 percent of the occurrences. Interestingly, the citation of the role of multiple factors in the analysis of China's civil air safety performance is a clear indication of the need for redundancy among aviation safety systems; the Chinese analysis did not explicitly identify system redundancy as a prioritized remedy.
[62] See "Chinese Airliner Hijacked to South Korea", *Xinhua New China News Agency*, 5 May 1983 and "Hijack in China Suceeds for First Time Despite Tough New Policy", *Associated Press*, 5 May 1983.
[63] Reported as Chunchon Airbase. See "A Chinese Airliner Touches Down at a South Korean Air Base after Causing National Air Raid Alert", *Reuters*, 5 May 1983, and "Hijacked Chinese CAAC Airliner Moves from Chunchon to Seoul", *Xinhua New China News Agency*, 15 May 1983.
[64] See "Hijacking to be Solved between China, ROK", *Jiji Press Ticker Service*, 6 May 1983.
[65] See Ted Chan, "China Wants its Hijackers Back", *United press International*, 16 May 1983.
[66] See "Statement by PRC Spokesman on Taiwan's Acceptance of Hijackers", *Xinhua New China News Agency* (in English), 20 August 1984.

The Trident hijacking was a significant problematic development for CAAC for three reasons.[67] First, it illustrated that the ineffectual management of civil air contingencies can be of extreme national importance, to include presenting long-term international consequences.[68] Second, it highlighted that CAAC's policy of refusing to cooperate with air pirates could precipitate disastrous results.[69] Third, it confirmed that assigning the bulk of the air security responsibility on the air crew, which the Central Government canonized for its courage and political reliability, was in itself an insufficient guarantor of flight security.[70]

CAAC individually addressed the sporadic hijacks and hijack attempts that occurred throughout the remainder of the decade, including the first direct hijacking of a commercial airliner to Taiwan in 1988[71] and the first commandeering of a Chinese international flight in 1989.[72] However, the sensational hijacking and subsequent crash of a Boeing 737-200 airliner in 1990 led to a major revision of CAAC's air security policy.[73]

On 2 October 1990, part of the post-Tiananmen era and on the heels of Beijing's hosting of the Asian Games, an armed hijacker commandeered a Xiamen Airlines Boeing 737 jetliner on a scheduled flight from Xiamen to Guangzhou, reportedly demanding that the aircraft divert to Taiwan.[74] The pilot apparently coordinated with ATC authorities to first land the aircraft in Hong Kong to refuel before proceeding to Hong Kong; however, the hijacker refused and threatened to detonate a bomb aboard the aircraft if it landed in Hong Kong.[75] As a standoff developed, the aircraft reportedly exhausted its fuel supply,

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[67] Each reason would otherwise enhance the PLAAF's position for military supremacy in China's ATM initiatives, except that the PLAAF had its own set of problems with military air defections to South Korea and across the Taiwan Strait.

[68] Interestingly, a civil air hijacking three years later (3 May 1986) would have similar political consequences, this time forcing contact between the civil air authorities of China and Taiwan. See "Hijacked Plane Will End China's 40-year Silence, Taiwan to Negotiate on Aircraft, *Los Angeles Times*, 13 May 1986, p.1, and Andrew Brown, "Taiwan Abandons its Principles to Talk with Peking", *Reuters*, 13 May 1986. Also, note that China has underscored its perspective that air piracy is a serious crime through its swift and severe punishment. See Michael Ross, "China Executes Air Pirates", *United Press International*, 19 August 1982.

[69] CAAC had a firm policy of not complying with hijacker demands. Two acknowledged previous hijacking attempts ended in physical struggles in the cabin, including the shooting deaths of a pilot and hijacker in one incident. Shen described China's policy toward air piracy at a news conference on 16 May 1983, following his return from Korea: "CAAC always gives priority to security and our crews also give first consideration to the safety of passengers. I think it is a correct policy to take appropriate measures to subdue would-be hijackers when the crewmembers are sure about the safety of the flight. Failure to take any measures to subdue the hijackers when safety is ensured is tantamount to encouraging the hijackers." See "Hijack Attempt Foiled", *Xinhua New China News Agency*, 25 July 1982, and Ted Chan, "Chinese Hijacker Shot and Killed", *United Press International*, 21 February 1983.

[70] On 26 May, less than three weeks after the incident, the State Council, in a ceremony before 1,800 CAAC members, conferred numerous awards on the Trident crew, to include double promotions for the two crew members wounded in the hijacking. See "Flying Crew Crushing Attempted Hijacking to be Commended", *Xinhua New China News Agency*, 28 July 1982; Phil Brown, "Bonuses, Rewards for Crew that Seized Hijackers", *Associated Press*, 14 August 1982; and "Hijacked Plane Crew Awarded by State Council", *Xinhua New China News Agency*, 26 May 1983. Also, some reports indicated that China had assigned security personnel to some flights – an "air marshal" system – to enhance air security, perhaps with demonstrated success. See "China Assigns Anti-hijacking Personnel to Commercial Flights", *Associated Press*, 25 February 1983, and "Chinese Hijacking Foiled Again", *United Press International*, 21 February 1983.

[71] See "Chinese Jet is Hijacked to Taiwan", Chicago Tribune, 13 May 1988, p. 8. Taiwan's early baseline policy on civil air hijackings from China is summarized in the phrase "ren-ji fenkai," or "separation of the person and the aircraft." Under this rubric, Taiwan authorities released civil airliners for return to China as quickly as possible, the hijackers remaining in custody in Taiwan. China viewed this policy as encouraging hijackings to Taiwan; in 1993, 11 aircraft were hijacked to Taiwan. See "China Accuses Taiwan of Encouraging Hijackings", *Agence France Presse*, 17 October 1993.

[72] See "Hijacked Plane Returns to China with Wife, Child of Hijacker on Board", *Associated Press*, 17 December 1989.

[73] See David Holley, "China Hijacking Goes Awry, 120 Die", *Los Angeles Times*, 2 October 1990, p. 1 and David Schweisberg, "Hijacked Chinese Plane Crashes; 'It was a Crematorium'", *United Press International*, 2 October 1990.

[74] See "Results of Skyjack Investigation, Local Management Shake-up Promised", *Xinhua New China News Agency* (in English), 9 October 1990.

[75] *Ibid.*

forcing the pilot to make an emergency landing in Guangzhou (Canton). As the plane taxied along the runway, a struggle ensued in the cockpit. The airliner suddenly veered out of control, colliding with a Boeing 757 passenger jet with 140 passengers awaiting takeoff for Shanghai and an empty Boeing 707 freighter. The incident killed 127 people and injured 60, destroying all three aircraft.[76]

The hijacking incident received sensational media coverage worldwide, as China's policy of not cooperating with hijackers became a central theme of concern and debate.[77] For its part, CAAC officially reported that it had instructed the pilot to obey the order of the hijacker and land the plane anywhere.[78] However, some reports claimed that the intent of some crew members to "render meritorious service" led to the air disaster.[79]

The disaster at Guangzhou led CAAC to adopt a more conciliatory policy toward civil air hijacking. However, the new philosophy of greater compliance would later encourage air piracy as an expedient method of fleeing the Mainland for Taiwan. In 1993, China endured 11 hijackings across the strait, forcing CAAC to again rethink its position of complying with hijacker demands.[80]

Military Aircraft Defections. The security concerns of China's civil air transport industry strengthened the PLAAF's position for unitary control of China's air space and ATM resources. However, the PLAAF and the PLA Navy Air Force (PLANAF) faced similar challenges in addressing military air defections to South Korea and Taiwan. Following four reported defections of Chinese military aircraft to Taiwan between 1960 and 1977 (including an IL-28 bomber defection to Taipei in 1965), China endured eight military air defections to South Korea and Taiwan between 1982 and 1989, including F-6 (MiG-19/Farmer) and F-7 (Mig-21/Fishbed) fighters and one PLANAF H-5 (IL-28/Beagle) light bomber.[81] In addition to the exodus, China also received at least four defecting military aircraft from Taiwan and Vietnam, and likely more from other nations along its periphery.[82]

Impact of the Pace of Development on Air Safety and Security. At least part of the reason for the spate of civil air accidents and hijacking incidents in China in the early 1990's can be attributed to the brisk pace of development of the jet transport industry. CAAC Director Jiang Zhuping, noted in CAAC's annual national conference in 1993 that China's airline industry was "expanding too fast in its attempt to compensate for the

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[76] See David Holley, "Death Toll 127 in Crash of Hijacked Airliner", *Los Angeles Times*, 3 October 1990, p. 4.
[77] The head of Boeing personally visited the site as part of the investigation and to survey the damage. See "Boeing Chief Visits China after Plane Crash", *Reuters*, 6 October 1990.
[78] See "Results of Skyjack Investigation, Local Management Shake-up Promised", *Xinhua New China News Agency* (in English), 9 October 1990.
[79] See Guy Dinmore, "China's 'No Surrender' to Hijackers May Have Caused Disaster", *The Reuter Library Report*, 3 October 1990.
[80] See "China Rethinks Policy of Complying with Hijackers", *The Reuter Library Report*, 27 December 1993.
[81] In addition to enhancing political indoctrination programs to maximize pilot loyalty to China, the PLAAF adopted a series of technical measures to prevent defections to Taiwan. In the late-1970's, the PLAAF purposely limited the number of training sorties and amount of fuel provided to fighter units along China's coastal regions, denying the range to defect to South Korea or Taiwan (in addition, fighter pilots were not permitted to train alone). See Melinda Liu, "China: Inside the Air Force", *Newsweek*, 25 July 1977, p. 50. By the mid-1980's, the PLAAF reportedly had installed a mechanical "anti-defection" device aboard coastal fighters that limited an aircraft's speed and fuel flow if the pilot violated pre-set instructions or distance limits. See "Anti-Defection Devices on China Planes Reported", *Los Angeles Times*, 15 October 1989, p. 5.
[82] See the accompanying table for additional details, attributed to multiple sources.

country's serious shortage of road and rail transport networks."[83] He added that CAAC would "try to balance the rising demands of economic expansion with concomitant improvements in crew quality and aircraft maintenance."[84] In addressing air safety Jiang specifically identified the priority as "upgrading telecommunication, navigation and radar systems and weather forecasting equipment to help avoid disasters which result from poor ground navigation."[85]

However, as the series of air accidents and hijackings continued unabated through early 1993, the CAAC leadership fell under increasing pressure to demonstrate progress. In October, Beijing's *Legal Daily* newspaper (*Fazhi Ribao*), published an article severely criticizing CAAC's safety ledger.[86] In unusually straightforward language, the article noted that "the air accidents which occurred one after another have cast a shadow on the Civil Aviation Administration of China and also turned the pledge of the CAAC to 'make 1993 a year of safety operation' into a visionary hope."[87] In CAAC's defense, the report also noted that by the end of 1992, China's 500 commercial air routes covered a range of 900,000 kilometers, a 25-fold increase over 1978; finally, it added that the "overloaded expansion and development" of the jet transportation industry had "exposed the deficiencies of CAAC."[88]

Impact of the Air Safety and Security Record on Public Relations. With the continuing increase in the number and proportion of foreign patrons using China's commercial airlines, CAAC's poor air safety and security reputation began to impact public relations.[89] As early as 1983, open source articles in the Western media began to criticize CAAC, first for the low quality of its civil air services and later for its poor air safety and security record.[90] Following the disastrous series of civil air accidents and hijackings from July 1992 to June 1994, foreign criticism of CAAC and China's airlines became an issue of national significance.[91] Critics noted that about one out of every 100,000 flights in China ends in a fatal accident, meaning that Chinese planes were 15 times more dangerous than the world average of one fatal crash per 1.5 million flights.[92]

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[83] See "Aviation Safety: China to Improve Air Safety Record after Worst Year in Memory", *Air Safety Week*, 18 January 1993.
[84] *Ibid.*
[85] *Ibid.*
[86] The official Xinhua New China News Agency's subsequent dissemination of the article was another clear indication of the central government's dissatisfaction with CAAC's performance. See "CAAC Pledge to Make 1993 a Year of Safety Nothing but a 'Visionary Hope'", *Fazhi Ribao*, 26 October 1993.
[87] *Ibid.*
[88] *Ibid.*
[89] CAAC's performance has always been of domestic concern, both before and after its reform. See "People's Daily Article on the Need to Improve Civil Aviation", *Xinhua New China News Agency*, 4 August 1980; "Civil Aviation management Criticized after Airport Incident", *Xinhua New China News Agency*, 20 August 1980; "CAAC Must Improve Leadership Style: The Key Lies in Improving the Style of Leadership", *People's Daily*, 24 February 1984; "Results of Skyjacking Investigation: Local Management Shakeup Promised", *Xinhua New China News Agency* (in English), 9 October 1990; "CAAC's Problems of Poor Service, Delays Still Arouse 'Strong Dissatisfaction'"; *Xinhua New China News Agency* (in English), 20 May 1994; and "Air Travelers Criticize CAAC's Delayed Flight, Safety Checks, Ticket Profiteering", *Xinhua New China News Agency* (in English), 22 September 1994.
[90] See Michael Ross, "Skies None Too Friendly on China's State Airline", *United Press International*, 10 June 1983; Michael Weisskopf, "China's No Frills Airline; Flying Fossils Fray Nerves of the Intrepid", *The Washington Post*, 13 June 1983; "China Must Address Safety Concerns", *Aviation Week & Space Technology*, 7 December 1992, p. 76, and Andreas Landwehr, "Air Travel in China Highly Dangerous: Flying in China is 'a Risk You Should not Consider'", *Ottawa Citizen*, 7 June 1994.
[91] Prior to 1990 – before the air accident death toll began to mount – much of foreign criticism of CAAC was limited to sarcasm. See "Does CAAC Mean 'China Airlines Always Canceled'?", *The Reuter Library Report*, 19 June 1988. Other sarcastic references to the CAAC acronym included "Cancel at All Costs" and "Crash All Around China" (attributed to various sources).
[92] China reportedly had one crash for every 100,000 domestic flights, twice as likely as world's second-worst nation (Colombia) and 15 times the world average; nine fatal crashes in the 30-month period before mid-June 1994 killed 542 people. See Andreas

The International Airline Passenger's Association (IAPA) cited China's domestic airlines as the least safe in the world; IAPA criticized CAAC for allowing the civil air infrastructure to lag in the wake of the rapid growth of the aviation industry, adding that "a complete and functional air traffic control system is lacking," and there is a "shortage of adequately trained staff."[93] The IAPA also cited "inadequate maintenance and safety procedures, an enormous shortage of qualified pilots, engineers, ground staff, mechanics and a primitive flight control system" as major shortfalls of China's civil aviation industry.[94]

Efforts to Enhance Civil Air Safety and Security. In late-1993, the Chinese Central Government and CAAC began to proactively address China's air safety and security problems through a wide range of interrelated, programmatic remedies. These commitments generally fall into five categories: leadership; system acquisition controls; legislative initiatives; training; and ATM infrastructure development.

Leadership. Ironically, one of CAAC chief Jiang Zhuping's last official duties as Director was to call for China to make airline safety "an overwhelming priority."[95] His plea, following the second hijacking to Taiwan of a Chinese airliner in four days – the ninth in 1993 – came at a conference to discuss a State Council circular calling for air safety improvements. By the end of the month, the Chinese Central Government replaced Jiang as the CAAC head, appointing Chen Guangyi as the new chief and raising the position to a ministerial post.[96] Chen, a member of the Chinese Communist Party's ruling central committee and who had served most recently as the local party chief in Fujian Province, replaced Jiang, who had served as director since February 1991; Jiang was subsequently demoted to vice director. The Central Government also replaced two CAAC vice directors in the shake-up.[97]

In January 1994, Vice-Premier Zou Jiahua underscored the Central Government's commitment to address China's civil air woes, asking CAAC to "institute stricter management and more rigorous discipline to ensure safer air traffic."[98] Zou's comments came at a meeting at CAAC headquarters to officially introduce CAAC's new senior leadership, comprised of Minister Chen and five vice directors: Jiang Zhuping, Yan Zhixiang, Li Zhao, Shen Yuankang and Bao Peide.[99]

Landwehr, "Air Travel in China Highly Dangerous; Flying in China is 'a Risk You Should not Consider'", *Ottawa Citizen*, 7 June 1994.

[93] *Ibid.*

[94] *Ibid.*

[95] See "Chinese Airlines Facing Safety Crisis: Aviation Chief", *The China Daily* (in English), 13 December 1993.

[96] See "China Aviation Boss Sacked after Spate of Crashes", *The Reuter Library Report*, 23 December 1993, and "CAAC Gets New Chief", *Agence France Presse*, 24 December 1993.

[97] *Ibid.* Chen's role, as an aviation industry outsider, also included the challenges of "weeding out corrupt and incompetent officials and improving discipline." See Renee Schoof, "China Improving Dozens of Airports to Boost Growth, Safety", *The Associated Press*, 7 April 1995.

[98] See "Vice-Premier Urges Civil Aviation to be Stricter, Safer", *Xinhua New China News Agency*, 6 January 1994.

[99] *Ibid.* Chen would serve as the CAAC chief from December 1993 to February 1998. Shen and Bao remain as two of CAAC's four vice ministers; Yan and Li serve today as CAAC consultants. See "The General Administration of Civil Aviation of China" (CAAC organization chart), *Sino Aviation News*, May 1997.

Civil air safety and security was the top priority of Minister Chen's agenda.[100] In March, he noted at an aviation conference that China punished over 120 people in 1993 because of their role in civil air accidents.[101] He added that China would train 600 pilots a year "to ease a severe shortage that leaves many planes under-utilized and forces pilots to fly long hours at the risk of safety."[102] Finally, Chen announced that CAAC would expand its ground security operations, installing additional more weapons-detection devices to prevent commercial air hijacking.[103]

Among Chen's safety and security programs, was a resurgent responsibility system, which became a significant leadership factor just a few months after its implementation. Following China's worst civil aviation accident – the crash of a China Northwest Airlines Russian-built Tupolev-154M airliner shortly after take-off at Xi'an in June 1994, killing all 160 persons on-board – Vice-premier Zou Jiahua personally led the accident investigation.[104] As a result of the Central Government and CAAC emphasis on responsible leadership, Gao Junyue, president of China Northwest Airlines was forced to resign, adhering to the agreement all airline presidents signed in March vowing to take personal responsibility for air accidents.[105] Chen Guangyi reportedly implemented the responsibility agreement in his first national aviation safety meeting.[106]

System Acquisition Controls. In addition to staffing key positions with more-capable leaders and adopting a performance-based review system, CAAC also suspended the creation of new commercial airlines and the acquisition of aircraft and air support equipment. Jiang Zhuping initiated this process in July 1993, noting the need to "reinforce air security."[107] Jiang announced that China would not approve applications to create new airlines and that CAAC would evaluate the "technical strength of flight and ground crews" and the "capacity of ground facilities" when considering requests for existing airlines to purchase new aircraft.[108] He added that CAAC would strictly examine new aircraft purchase and charter arrangements while strengthening the management of wet-lease programs.[109]

During the early stages of Minister Chen Guangyi's tenure as CAAC chief, China strengthened its control over new system acquisition. In July 1994, Vice-minister Shen Yuankang announced that CAAC would adopt an immediate 18-month moratorium on commercial aircraft acquisition.[110] He added that CAAC would redirect the resources earmarked for aircraft procurement to improving China's aviation infrastructure and

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[100] See "China Reiterates Pledge to Improve Poor Air Safety", *The China Daily* (in English), 2 March 1994.
[101] *Ibid.*
[102] *Ibid.*
[103] *Ibid.*
[104] See Tony Walker, "Tupolev Crash Adds to China's Air Woes", *Financial Times*, 7 June 1994, p. 4. This report notes that "some 15-20 percent" of China's civil air fleet is comprised of Russian-supplied Ilyushin, Antonov and Tupolev airliners. The report adds that the *China Business Times* quoted a CAAC official's comment that 17 accidents had occurred in China in the first five months of 1994, mostly involving "aircraft missing the tarmac on landing, mid-air engine failure and wing tips touching the ground on landing."
[105] See "China Airline Chief Announces Resignation over Crash", *Japan Economic Newswire*, 8 June 1994.
[106] *Ibid.*
[107] See "CAAC Suspends Approval for New Aviation Companies", *Xinhua New China News Agency* (in English), 16 July 1993.
[108] *Ibid.*
[109] *Ibid.*
[110] See Paul Lewis, "China Puts Brake on New Airliner Orders", *Flight International*, 20 July 1994.

training.[111] Under his tenure, CAAC adopted a safety inspection program to control the "quantity and scale" of civil airline expansion.[112]

Legislative Initiatives. CAAC augmented its personnel and acquisition initiatives with a series of state-supported legislative actions to "professionalize" the civil air industry on the basis of statutory authority.[113] These endeavors included civil aviation safety circulars, a robust "safety responsibility system," and China's first comprehensive aviation law, based largely on previous advances in airworthiness regulations.

In December 1993, CAAC and China's Ministry of Public Security jointly issued a nine-article civil aviation safety circular.[114] The circular outlined a wide variety of procedures and expectations related to passenger identification; luggage and baggage procedures and restrictions; and physical security.[115] The circular added that passengers and staff who violated the stipulations would "be investigated and punished by the public security bodies according to the Regulations on Control of Social Order and Punishment of the PRC and the regulations issued by the CAAC on civil aviation safety."[116]

Minister Chen's "safety responsibility system" expanded in early 1995 to incorporate safety responsibility contracts between CAAC and its subordinate airlines, airports, aviation colleges and local aviation administrations.[117] The system included the requirement to attain China's targeted civil air safety standards for 1995, which CAAC defined in clear quantitative terms.[118] The system also provided a package of awards and bonuses as incentives for maintaining high safety and security standards.[119] A "serious" civil air flight accident or hijacking would result in a fine ranging from 100,000 to one million renminbi,[120] and CAAC would hold the leaders or "legal persons" responsible for the incident.[121] Under Minister Chen Guangyi's leadership, CAAC reportedly consummated safety responsibility contracts with 36 administrative bureaus and airlines in 1994.[122]

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[111] *Ibid.* Li Jun, director of CAAC's planning department, later corroborated the redirection of funds earmarked for aircraft acquisition to ATC and safety. See Renee Schoof, "China Improving Dozens of Airports to Boost Growth, Safety", *The Associated Press*, 7 April 1995.

[112] See Zhang Ting, "1995: The Year of Airline Safety in China – Visiting Mr. Ban Yongkuan, an Official of the Aviation Safety Office in CAAC", *International Aviation*, March 1996, p. 24.

[113] In the early 1990's, China generally began to adopt and institute a justice system based on the rule of law; previously, China had largely vested statutory authority in its state organizations, many of which were influenced as much by individuals as by legislative code.

[114] See "Xinhua Outlines Contents of Civil Aviation Safety Circular", *Xinhua New China News Agency*, 15 December 1993.

[115] *Ibid.*

[116] *Ibid.*

[117] See "CAAC Contracts with Subordinate Entities", *Xinhua New China News Agency*, 26 January 1995.

[118] *Ibid.* The civil aviation safety goals for 1995 were: no serious flight accidents; while guaranteeing the safety of aircraft and passengers, air crew should do their best to prevent hijacking instances; the rate of flight accident signs should not be more than 1.9 per ten thousand flight hours, and signs of flight accidents caused by artificial reasons should not surpass 40 percent of the total signs; serious flight accidents caused by misconduct on air traffic must be put to an end; and the rate of danger and other flight accident signs must not be more than 0.05 per ten thousand sorties.

[119] In 1995, the "Safety Award Fund" consisted of 30 million yuan, more than $3.5 million. See Zhang Ting, "1995: The Year of Airline Safety in China – Visiting Mr. Ban Yongkuan, an Official of the Aviation Safety Office in CAAC", *International Aviation*, March 1996, p. 24.

[120] The renminbi – "People's money" – is China's monetary denomination. The floating exchange rate is approximately 8.2 renminbi per U.S. dollar.

[121] See "CAAC Contracts with Subordinate Entities", *Xinhua New China News Agency*, 26 January 1995.

[122] *Ibid.* CAAC reportedly awarded Air China, China Eastern airlines, China Northern Airlines, the Capital International Airport (Beijing), the Shanghai Hongqiao International Airport and the Guangzhou (Canton) Baiyun Airport with flight safety prizes ranging

CAAC also made substantial progress in instituting larger legislative statutes, the most significant being China's first comprehensive civil aviation law.[123] The promulgation of the civil air statute was based largely on CAAC's accomplishments nearly ten years earlier in acquiring U.S. Federal Aviation Administration (FAA) airworthiness certification for civil aircraft China wished to market internationally and to support its McDonnell Douglas MD-82 airliner co-assembly program.[124] CAAC intended that that regulation, a 29-article directive issued by the State Council, would "ensure the safety of civil aircraft, protect public interests and promote the cause of civil aviation."[125] Effective on 1 June 1987, the airworthiness regulation provided the first legislative sanctioning of CAAC's responsibilities and authority in China's civil aviation affairs.[126] It also vested in CAAC the authority to formulate detailed rules for the implementation of the regulations, to include cooperation with the Ministry of Aviation Industry to address relevant technical criteria.[127] On 30 October 1995, China adopted The Civil Aviation Law of the People's Republic of China at the 16th Meeting of the Standing Committee of the Eighth National People's Congress; the 16-chapter, 214-article law went into force on 1 March 1996.[128]

Training. Under Minister Chen Guangyi, CAAC also redoubled its aviation training efforts, again with the goal of "professionalizing" the support cadre, particularly in technical areas where China had an insufficient support base. CAAC initiated a wide variety of programs, including domestic training and training research; international commercial contracts; and participatory ventures with international organizations.[129] In 1994, China conducted over 100 classes to train more than 15,000 employees as part of its drive to enhance air safety.[130]

The air safety training effort included an official international component. In 1994, U.S. ATC specialists began to train lead controllers in China as part of a joint task force to improve air safety and capacity.[131] This program, which included CAAC, Boeing and two American consulting firms, was aimed at addressing practical real-world issues of ATM significance. The training provided an "integrated approach" to "bring

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from 10,000 to 20,000 yuan. On the negative side of the ledger, China Northwest Airline and the Yunnan Airlines registered serious flight accidents, while China Southern Airlines was held responsible for a hijacking incident.

[123] See "China Drafts First Law on Civil Aviation", *Xinhua New China News Agency*, 15 November 1995.

[124] See "Regulations on the Airworthiness of Civil Aircraft in China", *Xinhua New China News Agency*, 24 May 1987.

[125] *Ibid.*

[126] *Ibid.* It also outlined the role of the Ministry of Aviation Industry (MAI), China's primary civil aircraft manufacturing authority, which played a major role in identifying, developing and achieving civil airliner airworthiness standards. For more information in the relationship between CAAC and MAI, see Rusty Shughart, "China's Civil Aviation Industry: Modernization, Technology Transfer and National Defense", *U.S. Air Force Institute for National Strategic Studies*, 1 October 1996, 211 pages.

[127] *Ibid.*

[128] See Zhang Zhen, "International Air Transportation and its Management Regulations – Including an Overview of China's Civil Aviation Law", *International Aviation*, July 1996, pp. 22-25.

[129] For example, CAAC invited the International Air Transport Association (IATA) to provide an aviation English language course for air traffic controllers and pilots as part of China's effort to meet world air safety standards (IATA set up a similar program in Prague for Eastern European airlines). In addition, CAAC agreed to send the managers of several of its airlines to Geneva for courses in various business tasks, such as yield management and weight balancing. See "IATA's Aviation English Course Comes to China", *Aviation Week & Space Technology*, 1 January 1996, p. 34.

[130] See Zhang Ting, "1995: The Year of Airline Safety in China – Visiting Mr. Ban Yongkuan, an Official of the Aviation Safety Office in CAAC", *International Aviation*, March 1996, p. 24.

[131] The program was expected to help open up an estimated $2 billion market for ATC equipment including local, regional and national system management and overall flow control capabilities. See Paul Proctor, "Joint Effort Targets Chinese Air Safety", *Aviation Week & Space Technology*, 8 August 1994.

local, international and systems engineering expertise to the problem."[132] Its initiatives included recommendations on actions to improve safety and capacity along the routes of China's critical ATC triangle; in the classroom, top instructor controllers from Beijing, Shanghai and Guangzhou (Canton) worked to improve their English skills and to tailor a training syllabus to meet specific Chinese needs.[133]

ATM Infrastructure Development. The final component of CAAC's effort to enhance China's air safety and security was the renewed emphasis on modernizing the ATM support infrastructure. In 1995, Li Jun, director of CAAC's Planning Department, noted that CAAC "froze aircraft purchases in 1994 to free money for investment in better air traffic control and safety"; Li added that China would emphasize projects to "transform air traffic control, telecommunication, navigation and meteorology facilities."[134] He cited CAAC's plans for civil air radar coverage in the heavily populated area of eastern China by 1998 and initial transition to satellite-based ATM in the year 2000.[135]

In promoting its ATM support infrastructure, China opened its civil aviation construction to Western investment and assistance.[136] Westerners, limited to minority ownership, were forbidden to engage in ATC systems, which could "only be funded and administered by the Chinese government."[137] However, CAAC began to invest more heavily in the purchase and installation of Western systems; in 1996, it announced it would invest $720 million in ATC equipment during the ninth five-year plan.[138]

Administration of ATM Initiatives and Programs. Vice Minister Bao Peide, one of four CAAC vice-ministers, oversees the primary effort to address China's ATM challenges.[139] His major subordinate organizations include the Air Transportation Regulation Department; the Capital Construction and Airport Supervision Department; and the Air Traffic Management Bureau (ATMB).[140] Vice Minister Bao also has oversight authority for at least one commercial activity – the Air Communication and Navigation Aids Maintenance Company – and one technical research firm, the Engineering Advisory Company.[141]

Air Traffic Management Bureau. ATMB, led by Director-General Chen Xuhua, supervises most of CAAC's technical ATM work. Administratively, ATMB has seven subordinate divisions: ATC; Telecommunication; Radar and Navigation; Finance; Flight

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[132] *Ibid.*
[133] *Ibid.*
[134] See Renee Schoof, "China Improving Dozens of Airports to Boost Growth, Safety", *The Associated Press*, 7 April 1995.
[135] *Ibid.*
[136] In May 1994, China announced that it would allow such investment "on the condition that Chinese capital exceeds 51 percent of the total in any venture, and that Chinese citizens serve as chairman of the board and general manager." Other managers could be Chinese or foreign. See "Civil Aviation Construction Market Opened Partially", *Xinhua New China News Agency*, 28 May 1994.
[137] *Ibid.*
[138] See P.T. Bangsberg, "China Plans Invstment to Upgrade Air Control", *Journal of Commerce*, 10 May 1996, p. 4.
[139] Bao was once secretary of the party committee of the Guangzhou branch of CAAC. See "Defection of Taiwan Cargo Pilot to PRC", *Hsin Wan Pao* (Hong Kong), 5 May 1986.
[140] See "The General Administration of Civil Aviation of China" (CAAC organization chart), *Sino Aviation News*, May 1997.
[141] *Ibid.*

Information; Meteorology; and Technical Development.[142] The Technical Development Division conducts most of CAAC's CNS/ATM planning. Functionally, ATMB also coordinates the activities of China's seven ATMB bureaus, which are assigned geographically: Beijing, Shanghai, Shenyang, Xi'an, Chengdu, Guangzhou and Urumqi. In turn, each bureau has three functional divisions: Telecommunication and Navigation; ATC; and Meteorology.[143]

ATMB Staff Composition. ATMB's functional staff consists of nearly 11,000 personnel, with telecommunication and navigation positions accounting for nearly one-half of the total.[144] These positions include communication, navigation, radar and support personnel. The ATC staff consists of nearly 2,800 personnel, of whom certified air traffic controllers comprise nearly 60 percent;[145] the remainder consists of flight information specialists, dispatchers and miscellaneous ATC personnel. Finally, about 2,300 personnel provide meteorological support services to civil aviation, operating about 100 weather stations for meteorological observation and forecasting.

Overview of China's ATC Environment. Generally, CAAC oversees an uneven distribution of civil air traffic. First, more than 80 per cent of China's commercial air activity occurs in the east, which CAAC defines as the area east of Xi'an.[146] Second, there is only a nascent general aviation industry, meaning that few flights operate at lower altitudes. As a result, 80 per cent of China's commercial air operations take place at or above 9,000 meters.[147] Third, there is an uneven density of flight activity within the eastern sector. China's main airports – Beijing, Guangzhou (Canton) and Shanghai – represent the busiest air centers in China;[148] CAAC projects each of these airports will handle over 500 flights a day by the year 2000. In 1995, there were over 1.6 million commercial air take-offs and landings in China; over 60 per cent occurred in the regions under ATMB northern (Beijing) and southern (Guangzhou) bureau control.[149]

Air Space Division. Operationally, China sub-divides its civil air space into nine Flight Information Regions (FIR), 26 high altitude area control centers (ACC's) and 37 middle/low altitude ACC's.[150] The terminal facilities include three approach controls (Beijing, Guangzhou and Shanghai) and more than 100 civil airports, many of which include combined civil-military operations.[151] All of China's airports are tower

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[142] See CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the Joint Defense Conversion Commission (JDCC) (1996).
[143] Functionally, China consistently assigns its ATMB programs into the three main categories of Telecommunication and Navigation; ATC; and Meteorology.
[144] CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the JDCC (1996).
[145] In 1991, China had about 1,100 licensed air traffic controllers. See "The Air Traffic Control System in the People's Republic of China", *Federal Aviation Administration*, 29 July 1991, p. 2.
[146] This area is east of an imaginary line connecting Harbin, Shenyang, Beijing, Xi'an, Chengdu, Kunming and Jinghong.
[147] China continues to use the metric system to represent flight altitude within its air space; the ICAO standard is in terms of feet. International flights entering China's air space are required to report their altitude using the metric system.
[148] The route network connecting these cities is sometimes referred to as the "golden triangle" or "golden delta."
[149] CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the JDCC (1996).
[150] CAAC plans to reduce the number of high altitude control areas and medium and low altitude control areas to 10 and 25, respectively. There are no plans to change the number of FIR's. See CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the JDCC (1996).
[151] *Ibid.*

controlled. CAAC provides air surveillance for most of the civil air routes in eastern China above 7,000 meters.

Control and Utilization of Air Space and Resources. China's civil aviation industry enjoys a proud revolutionary heritage.[152] It traces its modern roots to the creation of "new China" in the late 1940's. However, over the ensuing 50 years, China's emphasis on military aviation limited the role and potential of civil aviation, resulting in a conservative philosophy on the control and utilization of national territorial air space and aviation resources. In the late-1980's, the military still controlled virtually all of China's air space, allocating certain routes for civil use.[153] However, as China's civil aviation continues to develop and expand – typically, by as much as 20 per cent each year – the operational need to collaborate on air space control and resource issues has become paramount.[154] As a result, the military continues to yield greater amounts of air space to CAAC, including a recent agreement designating 28 routes to civilian control.[155] However, the pace of transformation to balanced control and utilization remains a major concern, particularly as China's civil air operations continue to expand and as practical CNS/ATM efficiencies become possible.[156]

Current ATM Resources. Much of China's commercial air management limitations stem from its obsolescent equipment. China's civil air communication is limited to VHF radio contact, with radio hand-off between the 26 high altitude control areas. In navigation, the number and distribution of China's grid of terrestrial navaids – which includes about 360 NDB's, 130 VOR/DME sites, and 110 ILS stations – limit the dissemination of commercial flight navigation services.[157] China operates fewer than 100 radar systems devoted to civil aviation, about one-third of which are primary radar systems (PRS).[158] Many PRS are collocated with Secondary Radar Systems (SRS).

China's Current ATM Situation. China's current ATM system relies heavily on the support of its ground-based communication, navigation and surveillance (CNS) sub-systems; China's national ATC organizational structure and efficiency; and its domestic airport infrastructure. In recent years China has advanced relatively quickly in CNS infrastructure development and in airport construction, investing heavily in traditional

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[152] For the most comprehensive review of the modern history (since 1949) of civil aviation in China, see China Today: Civil Aviation Industry, 1989, 650 pages (in Chinese).

[153] In 1987, CAAC reported it had a fixed number of international routes (13) and domestic routes (about 200), in addition to being responsible for the air space surrounding civil airports (80). The military controlled the remainder, except for certain areas it assigned to the Ministry of Aviation Industry (MAI) and to low altitude use by helicopters and for agricultural spraying. See "Trip Report: T. Messier, E. Harris and J. Etgen, Beijing – People's Republic of China, 16-21 March 1987", *Federal Administration of Aviation*, p. 12.

[154] The PLA assigns only a small portion of China's air space for civilian control. The civilian flight corridor reportedly varies from 8-20 kilometers in width and with variable height. Some analysts have described these routes as "pipelines of airspace" or "ribbons in the skies." See Elizabeth Keck, "Spreading its Wings", *The China Business Review*, July-August 1995, pp. 12-15, and Thomas P. Messier, James Etgen, and Edward Harris, "Improving China's Air Traffic Control", *The China Business Review*, September-October 1987, pp. 26-31.

[155] The Chinese announced this transfer in January 1996, during the visit of Lt Gen Ed Eberhart, USAF Deputy Chief of Staff for Plans and Operations. General Eberhart led a U.S. team to China to visit ATC sites and research facilities as part of the JDCC.

[156] The "free flight" benefits of RNAV/RNP in China's remote western regions, for example, would be impossible without PLA concurrence. One Chinese ATM analyst describes China's ATM philosophy as "backward in means and conservative in methods." See Zhou Qihuan, "The Evolutionary Change of the Air Traffic Environment", *International Aviation*, October 1995, p. 6.

[157] CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the JDCC (1996).

[158] *Ibid.*

ATC and airport equipment.[159] But there are still many shortcomings and limitations in China's domestic civil air traffic environment. Generally, these weaknesses can be characterized into seven major categories:[160]

Line of Sight Signal Propagation. The performance limitations of line-of-sight radio (analog) propagation and radar operation greatly restrict the effectiveness and integrity of China's CNS system.[161] This shortcoming affects all aspects of CNS. In communication, China's air-to-ground (A/G) civil air contact relies on an obsolescent system of high frequency (HF) radio voice communication.[162] In navigation and surveillance, the limitations of radio beacons and radar systems hinder the effectiveness of China's entire grid of navigation aids (navaids).[163] In many areas, terrain, maintenance and security factors largely determine the location of ground-based, civil air support sites. The result is that the coverage of the civil air traffic support systems is non-continuous, including portions along the dense air traffic routes of China's eastern sector, where there remain gaps in coverage. In traditional aviation support services, many areas of northwest China are simply "a strip of blank space."[164] In addition, because of wave propagation instability and its susceptibility to interference and other phenomena limiting reliability, beyond visual range communication and navigation systems cannot meet many of China's CNS needs, particularly along oceanic routes and in areas of the hinterland.

Air-to-Ground Voice Communication. China's A/G contacts rely entirely on voice communication; there is no A/G data exchange network. As a result, the ability to share and exchange information between ground sites and aircraft is limited, the flow of information is inefficient and there is no potential to automate ATC services. In addition, the relatively low band width of voice communication leads to severe radio frequency congestion, particularly in urban areas. CAAC is just now overseeing a transformation to A/G VHF voice communication along the "golden triangle" routes; however, HF will continue to be used as a back-up.[165]

Terrestrial Communication. On the ground, the data exchange capability between China's ATC units is insufficient, still reliant largely on telephonic contact. The

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[159] However, the complexity of ATC systems integration continues to be a major shortcoming of China's national ATC structure. By 1994, China reportedly had purchased ATC equipment from at least 23 different companies worldwide. See Air Traffic Control Survey, 1992-93, *Jane's Information Group*, Coulsdon, U.K., 1993.

[160] See Zhou Qihuan, "The Evolutionary Change of the Air Traffic Environment", *International Aviation*, October 1995, pp. 5-7. Zhou, who also reports on ATM developments worldwide for *International Aviation*, summarizes China's national ATC limitations into seven major categories, noting that globally-coordinated CNS/ATM advances will "dramatically improve" China's ATC situation. Western analysts have also noted that China's shortages of ATC facilities, ground-based navigation aids and instrument landing systems, combined with its size, make it "the ideal market for satellite-based navigation systems." See Air Traffic Control Survey, 1992-93, *Jane's Information Group*, Coulsdon, U.K., 1993.

[161] The functional range of most conventional CNS systems is limited to about 200 nautical miles.

[162] Most conventional A/G radio contact worldwide now relies on VHF, as opposed to HF.

[163] In navigation, radio non-directional beacons (NDB); very high frequency omnidirectional range (VOR) sites and distance measuring equipment (DME) comprise this grid; for surveillance, these systems include primary surveillance radar (PSR) (which relies on radar "skin paint" returns) and secondary surveillance radar (SSR) (also known as "beacon interrogation"). The limitations of line of sight propagation degrades the functional utility of each of these systems.

[164] See Zhou Qihuan, "The Evolutionary Change of the Air Traffic Environment", *International Aviation*, October 1995, p. 5.

[165] CAAC envisions full VHF voice coverage at Flight Level 7,000 meters for the triangle routes; HF will become the back-up system. HF voice remains the principal means of A/G communication in the western part of China; CAAC sees satellite solutions for the A/G communication challenges of its remote areas. See CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the JDCC (1996).

flow of information between terrestrial sites is incomplete and not part of a cohesive network. With no means to collaborate, these sites are unable to dynamically track aircraft, forecast flight paths or detect potential conflicts.[166] Aside from manually sequencing the approach and landing of inbound aircraft, China lacks a true flow management capability. This shortcoming causes many back-ups, on-station waiting and delays among scheduled commercial air operations. As a result, China has only a marginally-functional Aeronautical Fixed Telecommunication Network (AFTN); the landline connections and time-consuming voice contacts remain as the backbone of ATC communication effort, including the coordination of civil and military air activity.

Procedural Air Traffic Control. Procedural control – based on flight plans, en route progress reports and time separation criteria to maintain safe distances between aircraft in proximity – remains as the principal means of ATC. This system of "strategic control" relies primarily on route, altitude and speed assignments;[167] as such, it often requires subjective decision-making on the part of ATC controllers to resolve conflict, which may arise from an extensive array of routine problems, including weather and maintenance factors. The human involvement increases the risk of error and misunderstanding, particularly significant in the case of China because of its lack of redundant ATC systems. China is just now beginning to test radar control along certain routes.[168] In October 1993, CAAC reportedly implemented radar control along the "golden triangle" routes, reducing lateral separation from ten minutes to five and cutting vertical separation from 1,000 meters to 600.[169] As a result, CAAC created four additional flight levels, effectively doubling China's civil air capacity along the corridors.[170]

National Air Route Structure. China's national air route structure is tied to the uneven distribution of ground-based navaids. This limitation allows for only conventional navigation between sites; it cannot support parallel or sequential routing. In addition, China's traditional concern for state security has resulted in a national emphasis on the military utilization of air space, severely limiting the efficiency and flexibility of civil air operations. Unlike the U.S., China has no National Route Program (NRP) to serve as a catalyst for the state transition to true ATM.[171] Nor does it have a National Airspace System (NAS) to develop and address the larger issues of space and air space utilization in the 21st Century.[172]

Civil-Military Air Space Management. In managing delineated air space and resources, China has many areas that are permanently closed to civil aviation. There is

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[166] *Ibid.*

[167] "Tactical control" uses a more flexible separation system, based on aircraft relative position and velocity vectoring. Tactical control is a baseline concept of true air traffic management, as opposed to conventional air traffic control.

[168] China's "three center" project will lead to a triple layer of radar coverage along the routes of its three major commercial airports: Beijing, Guangzhou (Canton) and Shanghai. See Chapter 3 for more details.

[169] See Air Traffic Control Survey, 1992-93, *Jane's Information Group*, Coulsdon, U.K., 1993.

[170] *Ibid.*

[171] See Bruce D. Nordwall, "Free Flight: ATC Model for the Next 50 Years", *Aviation Week & Space Technology*, 31 July 1995, pp. 38-39.

[172] See Gregory Burke, "Shaping the National Airspace System for the 21st Century (conference paper), AIAA/IEEE Digital Avionics Systems Conference, *Institute of Electrical and Electronics Engineers, Inc.*, FAA, Office of System Architecture, Washington, DC, Irvine, CA, 26-30 October 1997, pp. 4-1 to 4-7.

no flexible mechanism for military and civil aircraft to co-exist in the use of China's air space. As a result, civil air transportation operates under highly-defined conditions, primarily to avoid conflicts with military flight activity. Furthermore, the PLA's designation of air space for civil use changes frequently, due to military training, exercise and contingency operations.[173] Operationally, China conducts its ATC services for civil and military flight independently, requiring telephonic contact between dissimilar ATC sites to coordinate non-scheduled flight activity – a time-intensive process that degrades air safety and operational efficiency. Even among routes the PLA has designated for civil use, the military reserves the right to cross or utilize on a routine basis.[174]

ATM System Philosophy. Some Chinese CNS/ATM analysts view China's ATM system as "conservative and outmoded, lacking automation and operational efficiency."[175] To date, China has emphasized the acquisition of traditional ATC hardware to meet its CNS/ATM challenges. Much work remains to address the systems-related conceptualization of China's nascent ATM architecture and philosophy.

Enabling Technologies of the Emerging ATM System. With the existing shortfalls of China's current ATM system, outlined in the table on page 33, China finds itself on the cusp of the International Civil Aviation Organization (ICAO)-led wave of revolutionary change in the global management of civil air operations.[176] In accordance with ICAO's recommendations, China's current air traffic environment is beginning to reflect changes fostered by the enabling technologies of the emerging CNS/ATM system.[177] Chinese analysts point out that program advances in all four areas of CNS/ATM must form a complete set, be transformed individually and yet realized simultaneously to allow China to fully exploit the system's efficiency and achieve its economic benefits.[178] The recommendations are five-fold:

1. proceed with the orderly adoption of CNS/ATM system efficiencies.
2. use emerging CNS/ATM technologies to supplement existing, conventional systems.
3. gradually renew and replace.
4. maintain the qualities of regional features.
5. emphasize global coordination and cooperation.

Ongoing ATM Emphasis. In using emerging CNS/ATM technologies, China hopes to

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[173] See Zhou Qihuan, "The Evolutionary Change of the Air Traffic Environment", *International Aviation*, October 1995, p. 5.
[174] However, the PLA must coordinate its use of these routes with civil ATC controllers. See notes from CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the JDCC (1996).
[175] See Zhou Qihuan, "The Evolutionary Change of the Air Traffic Environment", *International Aviation*, October 1995, p. 5.
[176] ICAO, which has been very effective in designing global CNS/ATM advances under the FANS rubric, has been far less effective in addressing global air safety issues.
[177] One Chinese analyst points out that the future air navigation system (FANS) is actually the incorporation of satellite-based CNS with automated ATM systems, essentially, a combination of satellites, data links and computer networking with ATC applications. From a tactical standpoint, it requires a gradual transition from a ground-based to a satellite-based system. In the early stage, China hopes to initially establish a satellite-based system to supplement the existing structure, gradually transitioning to the satellite-based system as primary. In the later stages, except for some ground-based facilities that will serve as alternative or back-up systems, much of China's ground infrastructure would fall into disuse. The key issues of ATM automation are digitization, computer processing and their networking problems. See Zhou Qihuan, "The Evolutionary Change of the Air Traffic Environment", *International Aviation*, October 1995, p. 5.
[178] *Ibid.*

Major Limitations of China's Current Air Traffic Management System

Operational Background	*Limitations*
Communication	
air-to-ground communication relies on high-frequency (HF) radio voice contact; distribution of voice communication assets is uneven and incomplete	low system reliability and saturation levels due to HF radio line-of-sight limitations; gaps in functional coverage; limited range of effectiveness; non-automation and negative impacts of radio propagation phenomena
Navigation	
existing very high frequency (VHF) navigation equipment provides inadequate measures of performance; distribution of navigation assets is uneven and incomplete	primary – VHF Omni-directional Range (VOR) and Distance Measuring Equipment (DME) – have radio line-of-sight limitations; oceanic navigation relies on combination of non-precision Omega (now withdrawn) and Inertial Navigation Systems (INS)
Surveillance	
existing radar air surveillance equipment has limited performance capabilities	primary air surveillance system – Secondary Surveillance Radar (SSR) – has line-of-sight and range limitations
Air Traffic Management	
Air Traffic Control (ATC) support structure is based on obsolete equipment	low system reliability; low capacity for increased utilization
ATC new system procurement is a regional or local decision	ATC compatibility shortfalls limit ability to design and manage national ATC structure
ATC concepts and methods are highly constrained	procedural control, based on a strategic system of time-separation, limits air traffic flow and capacity
civil aviation A/G voice communication system is separate from the terrestrial communications network	non-integrated information systems have a limited capacity to distribute flight management data and information
ATC procedures are not automated	manual procedures highly inefficient; existing flight operations philosophy is highly conservative
national air route structure is inefficiently defined	fixed route allocation is based on distribution of navigation aids (navaids), limiting flight efficiency and flexibility
air traffic flow management capacity is highly limited	aircraft flow is managed manually, often by condition-based, subjective decisions
national air space division is inefficiently allotted and managed	civil air transportation operates in highly-defined airspace, primarily to avoid conflicts with military operations; the allocation of airspace designated for civil use changes frequently due to exercise and contingency operations
ATC services for civil and military flight operations are conducted independently	air safety is degraded by need for operational coordination; inefficient utilization of CNS/ATM resources

achieve several practical advantages. To varying degrees, China is now using CNS/ATM technologies to:[179]

1. meet the requirements of future air flight by raising national system capacity.
2. extend the coverage of air space to oceanic and border areas as well as to high altitude flight to form continuous, unbroken coverage.
3. implement a digital data exchange capability, improve the management of information transmission and raise the level of ATM automation to create a flexible, highly-efficient air traffic environment.
4. raise the timeliness and contingency capabilities of its ATC system to improve the dynamic utilization of its air space. The goal is to transition from procedural (strategic) control to automated, flexible (tactical) control.
5. expand the use of surveillance. While maintaining safety standards, reduce aircraft separation distances to make effective use of air space.
6. raise the accuracy of aircraft positioning; achieve four-dimensional navigation; promote area navigation (RNAV)[180]; develop shortened, direct air routes and expand flight operational freedom to economize flight time and fuel.
7. meet the CNS/ATM demands of various flight environments: dissimilar airspace; different levels of traffic density; different on-board avionics; different ground infrastructure. The new system must satisfy multiple customers, as well as address the problems of transiting the regional or national borders of global flight.

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[179] *Ibid.*

[180] The difference between traditional air navigation and area navigation (RNAV) lies principally in the structure of air routes. Traditional air navigation relies on a fixed, loosely connected network of navaids. Aircraft typically fly "station to station," using their position relative to the navaids' fixed, known location for navigation. Generally, while adherence to such a network is fixed and safe, it is also inefficient, rarely allowing for direct flight between airports. RNAV allows for "point to point" flight, permitting the flexible attainment of optimal routing based on the computerized calculation of flight variables, such as aircraft type, weather conditions and load factors. On-board avionics with Required Navigation Performance (RNP) capabilities (and operating in RNP-designated air space) allows users to select optimal flight profiles. The resultant positioning is absolute, as opposed to relative; the RNP-provided flexibility can potentially maximize the operational benefits of RNAV.

China's Perspectives on Air Traffic Management

Chapter 2

Perspectives on the Future ATM Architecture

Overview. A confluence of complex, interrelated variables combined to influence the structure and development of China's ATM system over the past 30 years. CAAC's call for sustained growth and expansion of civil air routes and operations to support and augment China's national economic construction saturated the capacity of the ATM system to support such a drive. The reorganization of the civil aviation command structure in the late-1980's further reduced the level of centralized control, allowing an unchecked number of new airlines and regional airport authorities greater autonomy in the acquisition of aircraft and civil ATM support systems. This development occurred within the context of CAAC's practical operational requirement to assume increased responsibility and control of China's air space from the PLA. However, the deteriorating civil air safety and security record, particularly in the early 1990's, reflected CAAC's inability to effectively manage the sustained civil aviation expansion, strengthening the PLA's predominant national security role in the control and management of China's national air space.

By the middle of the eighth five-year plan (1991-1995), CAAC began to reassert its authority over the development of China's civil transportation industry. In the mid-1990's, CAAC instituted a series of measures to address its civil aviation leadership; system acquisition; civil aviation legislation; training; and the development of ATM infrastructure. From 1994, it began to devise a CNS/ATM transition plan as the blueprint for China's adoption of the ICAO-led civil air navigation system of the future.

Convention on International Civil Aviation. As a member of ICAO and signatory to the Convention on International Civil Aviation, China has validated its commitment to design and develop its future CNS/ATM system to conform to international standards ICAO has coordinated and sanctioned. Particularly significant to China is Article 44 of the Convention. It codifies signatory state obligations to develop the principles and technology of international flight; it also requires its constituents to promote the standardization and development of air transportation to ensure global international aviation expands in a safe and orderly fashion.[181]

Background on ICAO Initiatives. To meet its obligation to coordinate the concepts and technical planning of global civil aviation, ICAO in November 1983 created the Special Committee on the Future Air Navigation System (FANS). In 1988, the committee published a report recommending ICAO coordinate the global transition of ATM from terrestrial-based technologies to space-based technologies, incorporating the advantages

[181] For additional background information, note that ICAO's headquarters in Montreal operates an excellent Internet web-site on its international civil aviation initiatives and programs. See http://www.icao.

of digital communication in the exchange and sharing of flight and air space management data. The global CNS/ATM concept led initially to a technical design phase, referred to as FANS I.[182]

Through successful proof-of-concept demonstrations, FANS I is now yielding to FANS II. In September 1991, during the Tenth Air Navigation Conference, the ICAO states approved a second FANS group – The Special Committee for the Monitoring and Coordination of Development and Transition Planning for the Future Air Navigation System – ushering in a global transition phase that more comprehensively defines practical operational standards.[183] The upshot of FANS II, which includes milestones and cost-benefit models for worldwide implementation, is the ICAO-coordinated recognition of the inherent limitations of extant analog, terrestrial-based CNS/ATM systems. From this acknowledgement, ICAO is now promoting ambitious efforts to develop and implement global CNS/ATM systems that rely principally on the inherent advantages of digital and satellite-based technologies. FANS II promises to sponsor the global transition from the current system of air traffic control to true air traffic management.[184]

China's ATM Endeavors to Meet ICAO Goals. On 12 January 1995, CAAC promulgated "The Implementation Policy for China's CNS/ATM," outlining China's plans to transition to the ICAO-sponsored "new system."[185] Administratively, CAAC, also created several ad hoc organizations to facilitate the evolution of its civil air management operations to future CNS/ATM standards. With the caveat that it will always reserve the sovereign authority of its territorial air defense and national security regulations, China has created a high-level leading group, an implementation office and an expert advisory group to implement the global CNS/ATM plan and to strengthen China's cooperation with other nations in transitioning to the new system.[186]

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[182] FANS I is a preliminary "free flight" concept. Free flight refers to "user preferred trajectories," a fundamental long-term goal of ATM. Commercial airlines have provided much of the impetus for ATM advances. Bruce Nordwall notes that American Airlines' collaborative "negotiated wind routes" program with the FAA has yielded an annual savings of $2.2 million. See Bruce Nordwall, "Road Map Leads FAA to 'Free Flight'", *Aviation Week & Space Technology*, 6 November 1995, p. 34. FANS I uses GPS signals and SATCOM links to provide addressed ADS (ADS-A) thus supporting flexible flight routing and reduced flight separation minima. For an overview of FANS I use in East Asia, see Perry Flint, "The Future is Now: FANS-1 Opens the Door to New Saving and Revenue Opportunities Across the Pacific", *Air Transport World*, January 1996, pp. 55-58. See G.A. Paulson, "ADS - Where, When and How?", *Proceedings of the Conference on Automatic Dependent Surveillance*, London, Royal Aeronautical Society, 24 March 1997, pp. I-VIII for an overview of development of ADS in civil aviation, including ICAO's work to develop Operational Requirements material and technical SARP's for the initial implementation of an Aeronautical Telecommunication Network (ATN)-based system. This report also describes the compatibility problems arising out of the two systems.

[183] ICAO promulgated this plan in October 1992, during its 29th Assembly.

[184] See "Major FANS Programs", *Jane's Airport Review*, 1 January 1998, pp. 32-33. This article provides an overview of FANS initiatives worldwide, citing China's Aeronautical Radio, Inc. (ARINC)-supported ADS and data link trials as among the most significant FANS programs in the Asia-Pacific region. For an overview of the importance of digital data links to FANS, see Bruce Nordwall, "Digital Data Links Key to ATC Modernization", *Aviation Week & Space Technology*, 10 January 1994, pp. 53-55. Also, see "Rockwell Eyes China ATM Market, Sees $ 1.9 Billion", *Aviation Daily*, 10 April 1996, p. 65. This article describes Rockwell International's ATM Systems Division ATM test with China as "the most comprehensive demonstration of a communication, navigation, surveillance/air traffic management (CNS/ATM) system ever accomplished." In the early 1990's, the four-engine Boeing 747-400 served as the primary platform for the development and testing of long-range data link operations over the Pacific Ocean using digital data communication. The jumbo jetliner was equipped with an aircraft condition monitoring system (ACMS) and an ACARS two-way communication system. See R.S. Stahr, "Implementing Data Link Across the Pacific", *SAE, Aerospace Technology Conference and Exposition*, Long Beach, CA, 23-26 September 1991, 9 p.

[185] See Zhou Qihuan, "The Evolutionary Change of Air Traffic Management", *International Aviation*, October 1995, pp. 5-6. CAAC outlines its FANS implementation policy and agenda in a joint manuscript, published in the July 1995 issue of *International Aviation* (in Chinese), see "CAAC's Implementation Policy for CNS/ATM", pp. 27-29.

[186] See CAAC joint manuscript, "CAAC's Implementation Policy for CNS/ATM", *International Aviation*, July 1995, p. 27.

China's ATM Transition Plan. China's evolution to FANS II – which CAAC describes as a "progressive transformation" – envisions full implementation of "rational, integrated and coordinated" FANS II standards by 2010, in accordance with the ICAO agenda. The actual pace of the transition will depend primarily on the stability of China's flight operations, assurances of continued flight safety, quantifiable operational benefit (primarily in terms of cost-effectiveness variables) and measurable improved quality in flight services. CAAC has publicly committed China to become more actively involved in FANS planning and implementation projects with the international civil aviation community, particularly within the Asia-Pacific region.

In doing its part to ensure the new system enjoys a globally-coordinated implementation and to accelerate the benefits of service providers to customers during the CNS/ATM transition phase, China has pledged to cooperate and engage in technical exchanges on a multitude of CNS/ATM issues. These include management supervision, technology application and formulation of rules and procedures.

China's FANS implementation philosophy is to utilize the practical elements of the emerging system to overcome the shortcomings and limitations of its existing CNS/ATM infrastructure.[187] It hopes to apply emerging technologies and methodologies to the existing conventional system to gradually satisfy globally-coordinated requirements, thereby supporting the new global aviation system.

From a timeline perspective, China acknowledges ICAO's 25-year CNS/ATM implementation schedule, which calls for system operability by the year 2010. However, CAAC Air Traffic Management Bureau (ATMB) Director Chen Xuhua notes that China will not achieve total satellite-based navigation until 2020.[188] To ostensibly meet the ICAO-coordinated goal, CAAC has divided its domestic transition plan into three distinct phases – near term, mid-term and long term – based roughly on the cycles of China's traditional five-year national economic programming.[189] For China, the near term encompasses ATM planning, system acquisition and equipment implementation that occurred prior to 1996. The mid-term, from 1996-2000, coincides with the ninth five-year plan; it includes intentions to field test emerging FANS technologies. The far term, spanning two five-year economic periods, will address technical maturation issues from the year 2001 to full system implementation by 2010. The overarching goals of CAAC's transition concept and execution efforts include advances in all areas of the CNS/ATM system, as outlined individually below and as provided in tabular form on page 38.[190]

Communication. In communication, CAAC has committed China to develop globally-integrated air-to-ground (A/G) and terrestrial networks. The immediate aim is to transition from the present system of simple analog radio broadcasting and

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[187] China's perspectives on these shortcomings are outlined in Chapter 1.

[188] See Wei Shijie and Zhang Ting, "Unimpeded Routes in the Blue Sky – An Interview with ATMB Director Chen Xuhua", *International Aviation*, May 1995, p. 29. China created CAAC's ATMB in August 1994 to manage all civil air traffic throughout the nation. Chen Guangren explains that because China's economy and technology are "insufficiently developed," China will lag behind the ICAO FANS global transition timeline by about five years. See Chen Guangren, "Preliminary Concept on AMSS Application in China", *International Aviation*, November 1992, pp. 46-47.

[189] See Chapter 3 for additional details.

[190] Chapter 3 outlines specific initiatives China is pursuing in its effort to transition to FANS.

China's Future Air Traffic Management Objectives

Current System and Limitation	*Future Objectives*
Communication	
A/G contacts limited to HF radio voice; low system reliability and saturation levels; propagation limitations; gaps in functional coverage	evolve to a satellite-based system, integrating A/G and terrestrial networks; adopt multi-functional combination of high-speed data and voice; develop a domestic digital ATN with open architecture for global integration
Navigation	
VHF equipment yields inadequate measures of performance; VOR/DME navaids have radio line-of-sight limitations; services among oceanic/remote regions inadequate	implement a GNSS-based system; gradually require aircraft to be equipped with RNP capabilities; GNSS will become sole navaid for en route/terminal phases of flight
Surveillance	
SSR equipment has line-of-sight and range limitations; limited performance/utility	establish a combination of SSR/ADS, particularly along high-density routes of eastern China; establish ADS first in remote western region
Air Traffic Management	
ATC concepts/methods highly constrained; procedural control limits aircraft flow and capacity; procedures not automated, highly inefficient	adopt strategic control (distance separation), supported by ground-based radar network and ADS; implement a computer-assisted flow management system (FMS)
national air route structure inefficiently defined; civil route allocation is based on fixed distribution of navaids, limiting flight efficiency/flexibility	develop a point-to-point system, based on principles of area navigation (RNAV)
national air space division inefficiently allotted/managed; civil aviation operates in highly-defined areas; allocation of air space for civil use changes frequently	expand the air space to permit simultaneous civil-military air operations; field a centralized ATC system
ATC services for civil/military flight operations conducted independently; air safety degraded by need for civil-military coordination; such contacts are bound by manual (telephone) procedures; inefficient use of limited CNS/ATM resources	promote the joint use of air space; improve civil-military data exchange capability; engage in joint consultations on air space use; adopt principles of strategically-separate time separation and RNP areas; improve capability for tactical coordination

landline connections to a low-speed, digitized communication system.[191] Eventually, China hopes to adopt a multi-functional combination of high-speed data and voice. The future system will integrate communications to meet the requirements of China's domestic air traffic services departments, service providers and customers. Ultimately, China's civil aircraft will communicate with ground ATC units through digital data transmissions via satellite and through a nascent aeronautical telecommunication network (ATN) architecture.[192] CAAC will design its ATN system as an "open architecture," using digitized information that can flow seamlessly to dissimilar networks, therefore meeting China's ICAO responsibility to support globally-integrated air communication.

Navigation. In support of air navigation, CAAC intends to implement a GNSS-based system to overcome the inherent limitations of the extant grid of land-based navigation aids.[193] China will gradually require aircraft operating in its air space to be equipped with standardized Required Navigation Performance (RNP) capabilities, meaning that an aircraft must meet certain navigation capabilities to operate in RNP-designated air space. Eventually, GNSS-provided navigation services will be the sole guidance requirement for the en route and terminal phases of flight as well as for precision and non-precision approaches and landings.

Surveillance. In air surveillance, China will incorporate ADS technology into its aircraft. ADS, part of the A/G communication data link, will automatically report an aircraft's real time, essential flight information – aircraft identity, GNSS position, heading, altitude and velocity – as "pseudo-radar" data to ATC centers and other consumers. In this regard, satellite-based ADS will emerge in China as a crucial ATM resource for surveillance of oceanic and low-density continental routes, particularly in China's remote regions, such as the provinces of Xinjiang and Xizang (Tibet). ADS will also augment Secondary Surveillance Radar (SSR)[194] operating in high-density traffic areas, such as the "golden triangle" routes of China's eastern territory.[195] China will likely first adopt ADS in its remote western region. This area now lacks a sufficient network of terrestrial radar devoted to civil aviation; it also contains a much lower density of commercial air traffic.

Air Traffic Management. Most of the CNS challenges CAAC now faces

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[191] China's en route communication still relies largely on extremely outdated HF equipment; VHF coverage is limited to airport terminal areas. Terrestrial civil communication relies on the public telecommunication network, which the Ministry of Posts and Telecommunication administers. For an excellent overview (although now somewhat dated) of China's general ATC challenges, see Thomas P. Messier, James Etgen, and Edward Harris, "Improving China's Air Traffic Control", *The China Business Review*, September-October 1987, pp. 26-31.

[192] CAAC's future ATN structure is outlined by Zhang Yaofan, "The CNS/ATM System and its Development in China", *International Aviation* (in Chinese), October 1996, pp. 45-46. CAAC intends for this system to integrate three major communication and surveillance sub-systems (VHF communication, AMSS and SSR-S) to support aeronautical operational communication (AOC) and ATC requirements.

[193] An FAA ATC technical assistance team visit to China in 1991 noted that China had 41 VOR's, of which 25 provided DME capabilities. Of China's 40 ILS, all were Category I, with the exception of Beijing, which was in a test phase of CAT II transition (see *The Air Traffic Control System in the People's Republic of China*, FAA, 29 July 1991, p. 4). An earlier report, *FAA-USAF Field Trip – 14-20 May 1989*, described China's air space system as "based on a 1953 Soviet design with two NDB's for rectangular approaches and for en route navigation." (p. 2)

[194] SSR relies on beacon-based interrogation; primary surveillance radar (PSR) is the traditional "skin paint," arising out of World War II.

[195] The "golden triangle" – sometimes called the "golden delta" – refers to the high-revenue, high-density routes that link Beijing, Shanghai and Guangzhou (Canton).

are essentially equipment or hardware issues. However, in ATM CAAC faces the formidable challenge of complex systems integration, most of which must occur as China's commercial air traffic continues to operate and expand. Much of the system integration effort must involve the PLA and the PLAAF; their active support of solutions to China's CNS/ATM challenge will be crucial to the success of the transition.[196] As China begins to realize the benefits of its new air management system, CAAC will face significant problems in assuring the flexible, efficient use of air space and exploitation of the nation's limited flight resources. China views flight safety, operational stability, air traffic flow management and economic organizational structuring as key sub-components of the ATM challenge.[197] Equally important will be the "unquantifiable" cultural and domestic political issues that will emerge as major factors in the outcome of the ATM challenge.[198]

Guiding Principles of FANS Transition. CAAC has divided its guiding principles for CNS/ATM implementation into two major categories. The first addresses "universal" considerations suited to the overall CNS/ATM system; it contains six general guiding principles China will adhere to in fostering its CNS/ATM development. The second category consists of special guiding principles related to the navigation system challenges of satellite technology and global system coordination. This category is sub-divided into communication and navigation issues.[199]

General Guiding Principles. CAAC cites six general guiding principles for China's CNS/ATM development.[200] In accordance with these guidelines, China will:

1. fully carry out the duties and rights of the ICAC.
2. meet and strengthen its authority for air security and safety for all air

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[196] This is not an insignificant factor. China's involvement in the U.S.-China Joint Defense Conversion Commission (JDCC) was characterized by a lack of coordination and agreement between CAAC, the ATMB, the PLA/PLAAF and the Commission of Science, Technology and Industry for National Defense (COSTIND). See Robert Butler and Rusty Shughart, "The Air Traffic Control (ATC) Initiative: A Case Study in U.S. Decision-making and U.S.-China Relations", *U.S. Air Force Institute for National Security Studies*, (forthcoming).

[197] See CAAC joint manuscript, "CAAC's Implementation Policy for CNS/ATM", *International Aviation*, July 1995, p. 27.

[198] There are several accounts – some controversial – of the impact of Chinese culture on its civil aviation operations. E.E. Bauer's *China Takes Off: Technology Transfer and Modernization*, University of Washington Press, Seattle, 1980, provides an excellent and at times entertaining overview of China's initial efforts to incorporate Boeing jumbo jetliners into its commercial air fleet. Paul Phelan, "Cultivating Safety: Cultural Differences in the Cockpit Must be Ironed Out if Air Safety is to Continue to Improve", *Flight International*, 24 August 1994, pp. 34-36, questions the willingness of the airline industry, in general, to release information on safety standards and specific incidents involving commercial air travel. He cites a Boeing study that indicated that the region defined as "Asia-Pacific and the Asian subcontinent" experienced 5.9 crew-caused airliner accidents per million departures from 1959 to 1992, the highest in the world (the North American rate was 1.3). The Boeing report cites "complex and interacting cultural factors" as likely contributing to the disparity. Don Phillips, "Aviation Safety vs. National Culture? Boeing Takes a Flyer", *International Herald Tribune*, 23 August 1994, p. 2, notes that Boeing refers to its study as one that offers "only a suggestion" of the role of culture to aviation safety. He adds that the issue as sensitive because it "inevitably raises the issue of race, and because Boeing runs the risk of inadvertently insulting some of its customers." Finally, China itself has taken steps to address the human and cultural aspects of civil aviation. Noting that "team efficiency is the crux of human factors in [civil aviation] training", CAAC itself has adopted the principles of crew resource management (CRM) and line oriented flight training (LOFT) as core elements civil air training programs. See Liu Hanhui (CAAC), "Human Factors in Chinese Civil Aviation Training", *Designing Instruction for Human Factors Training in Aviation*, Avebury Aviation, 1997, pp. 272-278. Concerning China's education standards, particularly regarding science and technology, see Chen Shilu, Yan Hui, Cai Yuanli and Zhu Xiaoping (Northwestern Polytechnical University), "The Historical Progress and Development of Space Technology and its Education in China" (conference paper), *International Astronautical Congress*, 7-11 October 1996, 12 p., and M.L. Spearman, "Some Observations on Chinese Education" (conference paper), *NASA Langley Research Center*, Hampton, VA (Design and Technology Meeting, Dayton, OH), 20-22 October 1986, 14 p.

[199] The Chinese view satellite surveillance – in the form of ADS – as a satellite communication application; as a result, CAAC's guiding principles for surveillance are a sub-set of its CNS/ATM communication policy.

[200] See CAAC joint manuscript, "CAAC's Implementation Policy for CNS/ATM", *International Aviation*, July 1995, p. 27.

space within its administrative jurisdiction. In implementing future high-technology, satellite-based ATM systems, China will reserve its right to not jeopardize its national sovereignty interests by allowing foreign intervention or encroachment into its civil air operations.

3. abide by coordinated ICAO standards and recommended practices (SARP's), as outlined in the ICAC.

4. abide by ICAO's globally-coordinated CNS/ATM transition plan and the guiding principles of its implementation.

5. in the use of satellites as the foundation of regional, national and global aviation support services, require that satellite service providers charge only reasonable fees from national, aviation and other miscellaneous air service consumers.

6. ensure that all equipment and facilities of its new air system satisfy CAAC's published airworthiness standards, thereby meeting China's domestic air security and safety concerns.

Special Guiding Principles.

Communication. CAAC cites four special guiding principles to support the global integration of air communication, to include its unique surveillance features.[201] In accordance with this guidance, China will:

1. field only air satellite communication technology that conforms to ICAO SARP's.

2. utilize only satellite technology that guarantees the capability for secure air communication; such service must guard against harmful interference.

3. in accordance with the requirements of the prioritized ranking of ICAO SARP's, ensure that the priority for air safety communication always outweighs the priorities of non-air safety and non-Air Traffic Services (ATS) communication.

4. ensure its national ATN construction and technology policy selection and application provides CAAC with management and limitation authority for all sub-network communication, including the right to approve equipment and services.

Navigation. To support the global integration of air navigation, CAAC cites three special guiding principles.[202] China will ensure that:

1. its air safety navigation signals and supporting communication signals are not affected by harmful interference.

2. its future satellite navigation system meets the precision and timeliness requirements of integrity, malfunction warning, reliability, continuity and information/signal enhancement to support the functions and corresponding RNP standards for all stages of flight.

3. all avionics required of FANS meets CAAC airworthiness standards.

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[201] *Ibid.*
[202] *Ibid.*

ATM Technology Policy. In embarking on the transition to the new CNS/ATM system, CAAC has also pledged that China will adhere to a significant array of policies related to CNS/ATM technology, including policy regarding avionics.[203]

Communication. In communication, China's future satellite-based system will emerge from the gradual testing, validation and utilization of communication systems across several aspects of civil aviation support. There are four areas of technical policy concern.[204] China will:

1. use domestic, regional or international satellites for voice and data link services. These services will employ CAAC or other ground stations and networks using ADS, GPS and SAT formats to meet the A/G communication and surveillance requirements for aircraft operating along oceanic routes and for routes in China's remote regions.[205]
2. use domestic or regional geostationary satellites to establish a domestic surface communication network. This network will link the primary trunk line communication needed to meet CAAC's domestic telephone; data; telegraph; weather and flight information data base; and airline data exchange and transmission network functions.
3. continue to develop a network of remote ground stations (RGS) that use satellite VHF channels to support en route operations. The RGS network will expand and complete the scope of VHF coverage for en route communication.[206]
4. use satellite links to resolve existing radar data transmission and networking problems along the congested flight routes of eastern China.

During the early part of the mid-term phase of the transition plan (1996-2000), China intends to establish its A/G VHF data communication network.[207] This network will provide the connectivity for the transmission and exchange of information and data between ATC, airline operations centers (AOC) and the AAC. During the mid-term phase of the transition plan, CAAC will complete the construction of the network of ground earth stations (GES) that supports the aeronautical mobile satellite service (AMSS) system. In finalizing this network, CAAC intends to continue to research, test and prove the utility of AMSS operations in China.[208]

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[203] *Ibid.*
[204] *Ibid.*
[205] China's references to "remote regions" typically refer to the western provinces of Xinjiang and Xizang (Tibet). These areas lie west of Xi'an, beyond the more heavily utilized air space of China Proper.
[206] CAAC plans for each RGS to provide radial coverage of approximately 350 kilometers at high altitude, defined as the trunk routes at and above 7,000 meters ASL (approximately Flight Level 210). See CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the JDCC (1996). Note that China continues to use the metric system to represent flight altitude within its air space; the ICAO standard is in terms of feet. International flights entering China's air space are required to report their altitude using the metric system.
[207] Obsolescent HF systems now remain the standard.
[208] The development of a flight management system (FMS) incorporating AMSS communication instead of HF voice communication is an inherent component of CNS/ATM. China has researched AMSS message processing procedures based on a VHF data link, using an onboard ACARS/Aircraft Condition Monitoring System (ACMS) system and ground station to implement the data link and adopting the SITA network as a ground communication network. See Lu Boying and Zhu Qiling (Beijing University of Aeronautics and Astronautics), "The Message Processing Techniques on VHF Data Link", *Pacific International Conference on Aerospace Science and Technology*, National Cheng Kung University, Tainan, Taiwan, 6-9 December 1993.

In realizing its transitional air communication system, China will utilize the Aircraft Communication Addressing and Reporting System (ACARS) as the focal point of its early-stage ATN system.[209] At the same time, China hopes to actively research, test and prove the application of ATN technologies with the goal of building upon its existing technology and systems to gradually transition to the Open Systems Architecture (OSI) of the International Standardization Organization (ISO).

Navigation. CAAC has five areas of concern in developing its technology policy regarding navigation.[210] China will:

1. utilize GNSS as the primary means of navigation for the en route and terminal phases of flight and for precision and non-precision approach and landing operations.
2. actively participate in and help organize technical cooperation, research and implementation efforts related to the standards and procedures of GNSS Category I and Category II/III precision approach and landing operations.
3. ensure the continued utility of GNSS services, China intends to gradually construct a series of domestic Wide Area Augmentation Stations (WAAS). WAAS will ensure the integrity, reliability, accuracy and continuity of GPS signals and services throughout all phases of civil flight.
4. pursue the RNP concept, principally to define a more flexible air route structure and to develop an area navigation (RNAV) environment.
5. adhere to the ICAO-coordinated recommendation to cease research and development efforts on the Microwave Landing System (MLS).[211]

Surveillance. In developing its future air surveillance capability, China intends during the early part of the mid-term phase of the transition plan (1996-2000) to begin applied SATCOM/ADS project testing along the oceanic routes and among the routes of China's remote western region. In principle, air surveillance of flights within Chinese air space – including international flights terminating in Chinese air space – will rely on Chinese or regional satellites. Surveillance of flights on oceanic or international routes will require China to use international satellites; through standardized procedures, these aircraft will enter the CAAC ground network, with CAAC itself responsible for managing network control.

Avionics. CAAC has pledged that China will expedite the outfitting and retro-fitting of the avionics of its civil fleet to meet international standards and airworthiness

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[209] The Aircraft Communications Addressing and Reporting System (ACARS), developed by the Aeronautical Radio, Inc., will support a three-phase VHF communication upgrade for China. See Chapter 3 for a more complete description. Generally, ACARS furnishes Automatic Terminal Information Service (ATIS) and Terminal Weather Information for Pilots (TWIP) data; these services are seen as highly effective in future efforts to improve the efficiency of civil air space utilization. In particular, the FAA's TWIP program directly provides pilots with Terminal Doppler Weather Radar and Integrated Terminal Weather System data, rather than relying on voice communication. Two types of TWIP messages are generated: a text-only message, intended for the typical ACARS cockpit, and a character-graphics map for cockpit printers. See Andrew P. Denneno, Steven D. Campbell, C.R. Storm and R.K. England, "The Terminal Weather Information for Pilots Program", *Proceedings on the Workshop on Wind Shear and Wind Shear Alert Systems*, Oklahoma City, OK, 13-15 November 1996, pp. 34-42.

[210] See CAAC joint manuscript, "CAAC's Implementation Policy for CNS/ATM", *International Aviation*, July 1995, p. 27.

[211] In 1995, ICAO rescinded its mandate that all international airports have MLS by January 1998. See Philip J. Klass, "ICAO Drops MLS Mandate", *Aviation Week & Space Technology*, 17 April 1995, pp. 30-31. ICAO is now recommending augmented GNSS as the means of future precision and non-precision approaches and landings; CAT II/III capability is targeted for 2015.

regulations for the FANS II transition period. CAAC will gradually complete its avionics airworthiness examinations and approval work through the use of relevant laws and decrees; regulations; and standard norms.[212] China began to upgrade the avionics of its civil fleet in 1995.

Air Traffic Management. In developing China's ATM capabilities, CAAC cites three main components of its technology policy.[213] China will:

1. during the early part of the mid-term phase of the transition plan (1996-2000) initiate research and evaluation projects in the automated flight plan processing and flow control aspects of air traffic services (ATS).
2. in the near term, use international technical exchanges and its domestic task group to map out China's ATS procedures related to FANS.
3. create a research group and many sub-projects to research the systems integration and transition agenda for ATM application in China.

Key Implementation Issues. In formulating its guiding principles and technology policy, CAAC has created the planning foundation for China's transition to FANS. In carrying out this transition, CAAC sees five issues as key to its implementation efforts.[214]

Standardization and Procedures. CAAC notes that in the globally-coordinated FANS transition plan the creation of technology standards along with flight procedures and ATS procedures will foster the new system's safety and operational benefits.[215] CAAC has committed China to do its part by actively participating in international exchanges and technical cooperation efforts, including the testing, demonstration and operation of appropriate FANS initiatives along China's air routes.[216]

FANS Equipment Evaluation and Validation. CAAC has pledged that China will adhere to ICAO standards and recommended measures in completing its new CNS/ATM system.[217] CAAC's examination and approval of China's A/G facilities and equipment will ensure China meets all standards, regulations and procedures relevant to FANS.

Pre-operational System Testing and Verification. In transitioning to FANS, CAAC notes that it is imperative to ensure the continuity of the existing system of air traffic services – principally in terms of safety guarantees – as well as the economic benefits to management, services and operations.[218] China will continue to adhere to the air navigation regulations and transition plan for ICAO and the greater Asia region.

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[212] In October 1995, the 16th Meeting of the Standing Committee of the Eighth National People's Congress officially adopted "The Civil Aviation Law of the People's Republic of China." See Zhang Zhen, "International Air Transportation and its Management Regulations – Including an Overview of China's Civil Aviation Law", *International Aviation*, July 1996, pp. 22-25.
[213] See CAAC joint manuscript, "CAAC's Implementation Policy for CNS/ATM", *International Aviation*, July 1995, p. 27.
[214] *Ibid.*
[215] Bruce Nordwall notes that technology is no longer a stumbling block to ATM modernization. The real delay in global ATM advances is the time-consuming task of building international consensus on new system and management standards. See Bruce D. Nordwall, "Standards Main Hurdle to New ATC Technologies", *Aviation Week & Space Technology*, 16 May 1994, pp. 46-47.
[216] See Bruce D. Nordwall, "Asia/Pacific Leads FANS-1 Progress", *Aviation Week & Space Technology*, 12 August 1996, pp. 48-49.
[217] See CAAC joint manuscript, "CAAC's Implementation Policy for CNS/ATM", *International Aviation*, July 1995, p. 27.
[218] *Ibid.*

Regarding the CNS/ATM sub-systems, China will engage in pre-operational testing and verification projects for en route and terminal operations.[219]

Training. China will expand and perfect the training of its management, service and operational personnel regarding new technologies. CAAC is actively considering international assistance and cooperation initiatives in the technical aspects of the new CNS/ATM system.

Orderly Transition. In the near term, CAAC will establish specific plans and programs for China's CNS/ATM transition, based on its national implementation policy.[220] CAAC hopes to nurture a uniform transition from China's existing system to FANS while maintaining flight safety and efficient air operations. In meeting this goal, CAAC pledges to consider and coordinate its planning with the transition plans of the flight information regions of nations and areas along China's periphery.

Funding Issues. The published version of CAAC's "Implementation Policy for China's CNS/ATM" does not address the key issue of how China will fund its ATM modernization.[221] Generally, there are few open source references that provide China's perspectives on ATM financing. ATMB Director Chen Xuhua notes that CAAC has procured weather, navigation and ATC equipment with a Japanese loan of $100 million.[222] However, it is unclear if these procurements are independent initiatives or fall under the rubric of the CNS/ATM transition plan.[223] At least two other sources are possible: programmed funding as part of the traditional five-year planning cycle and direct international involvement.

Ninth Five-Year Plan. In 1996, CAAC announced that China would invest $722 million ($6 billion yuan) to update its ATC systems over in the next five years, the largest such investment to date.[224] CAAC Deputy Director Bao Peide noted that the funds would be used on over 1,000 infrastructure projects to improve ATC. He added that China would channel over 90 percent of the funds to "improve communication, navigation and radar equipment"; the remainder would be invested in CNS/ATM.[225]

CAAC's investment announcement added that China will focus on improving the ATC in the eastern part of the country, to include a "three center" project to provide full radar coverage for China's three main airports: Beijing, Shanghai and Guangzhou

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[219] *Ibid.*

[220] *Ibid.*

[221] Generally, nearly all large countries around the world now face a similar resource dilemma, realizing the long-term benefit of ATM modernization, yet incapable or unwilling to invest to accrue such dividends. In the U.S., the FAA has called for a collaborative effort with industry as the means to modernize ATM. See Edward H. Phillips, "Free Flight Poses Multiple Challenges", *Aviation Week & Space Technology*, 25 March 1996, p. 27.

[222] See Wei Shijie and Zhang Ting, "Unimpeded Routes in the Blue Sky – An Interview with ATMB Director Chen Xuhua", *International Aviation*, May 1995, p. 29.

[223] Some reports suggest CAAC is collaborating with Japan's Civil Aviation Bureau to develop and fund its future ATM systems; China has reportedly used financing from Japan to construct about 100 satellite ground stations for improved navigation. See "China's Aerospace Industry: The Industry and its Products Assessed", *Jane's Information Group*, March 1997, p. 109.

[224] See "Air Traffic Control Systems to be Updated", *Xinhua New China News Agency*, 7 May 1996.

[225] China plans to spend about 6 billion yuan ($722 million) to update its ATC systems; only 440 million yuan, approximately $53 million, will be invested in true ATM systems. One analyst described CAAC as using the $53 million to "kick-start funding for mid-term CNS/ATM system development." See Paul Lewis, "The Long March", *Flight International*, 6 November 1996.

(Canton). These centers, to be linked by a network of radar installations, will serve as en route control centers for all major air routes in China's eastern provinces, which account for about two-thirds of China's domestic civil air operations. The goal is to cover these main domestic routes with triple radar surveillance layers by the end of the century, to improve safety and reduce the intervals between aircraft departures and landings.[226]

During its eighth five-year plan (1991-1995), China spent over $400 million (3.5 billion yuan) to update its ATC systems. However, CAAC former Minister Chen Guangyi has noted that China's ATM investment is far short of the required level; he has urged China's aviation industry to experiment with new forms of domestic and international financing.[227]

International Financial Involvement. Aside from international loans, China has sought foreign financial involvement in the form of investment and even donations. China had previously barred direct foreign investment in ATM core systems because of national security implications; however, government loans from France, Japan, Kuwait and the United States and Kuwait have occurred.[228] In addition, the Hughes Corporation in 1996 donated $18 million in equipment for a satellite communication network linking 97 airports; the donation represented 70 per cent of the project's total cost.[229]

To augment these international programs, CAAC in 1995 sent a large delegation to the U.S. seeking investment for domestic airport construction projects. CAAC Planning Department Director Yang Yinbao cited this visit as "the beginning of a push to attract foreign cash into all areas of aviation infrastructure."[230]

Market Incentives and Cost-Benefit Analysis. The willingness of some organizations to contribute ATM equipment and services to China likely stems from the potentially lucrative market it represents. The consulting firm of Booz-Allen & Hamilton, which collaborated with the Rockwell Corporation in comprehensive satellite-based ATM system demonstrations in China, estimates that market value at nearly $2 billion.[231] The analysis indicates China could save more than $4.4 billion over 20 years by modernizing its ATC system. In addition, the analysis suggests China can finance its satellite-based system entirely through user fees.[232] U.S. Embassy Beijing sources, industry analysts and some foreign business representatives feel that CAAC will be unable to disperse all $720 million earmarked for ATC in the ninth five-year plan, due primarily to technical planning problems. However, most analysts concur that China is serious about updating its ATC infrastructure. It is generally believed that China could spend as much as $400-500 million on ATC equipment by 2000-2001, and possibly up to $1.25 billion by 2004-2005.[233]

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[226] *Ibid.*
[227] See "China to Invest in ATC Upgrades", *Flight International*, 15 May 1996.
[228] See "China to Invest $722 Million for Air Traffic Control", *Deutsche Presse-Agentur*, 2 June 1996. For China's policy on ATC investment, see "Civil Aviation Construction Market Opened Partially", *Xinhua New China News Agency* (in English), 28 May 1994.
[229] *Ibid.*
[230] See "China's Aviation Sector Drumming Up Foreign Funds", *Agence France Presse*, 20 May 1995.
[231] See "Rockwell Eyes China ATM Market, Sees $1.9 Billion", *Aviation Daily*, 10 April 1996, p. 65.
[232] *Ibid.*
[233] See Joel Fischl, "China Air Traffic Control Equipment Market", February 1997, U.S. and Foreign Commercial Service (US&FCS), American Embassy, Beijing, *FT Asia Intelligence Wire - Industry Sector Analysis*, 4 March 1997.

China's Perspectives on Air Traffic Management

Chapter 3

Perspectives on the ATM Transition to FANS

Overview. In the 1970's, shortly following China's initial acquisition of commercial jetliners, CAAC began the long process of upgrading the national ATM infrastructure to support and enhance a modern air transportation industry. Prior to the eighth five-year plan, most of China's ATM system acquisitions were independent and isolated procurements, not part of a coherent, planned national ATM architecture. Beginning with the eighth five-year plan – and coincident with "external" forces in the form of ICAO, the FAA and Boeing – China began to formulate, adopt and institute a viable FANS transition plan that includes global conceptualization; specialized training;[234] management focus; ATM research and development; and national resourcing. Through these initiatives, further solidified in the current five-year planning cycle, CAAC has begun to reassert its authority over the safe, efficient development of China's civil air transportation industry.

Initiatives Prior to the Eighth Five-Year Plan. The near term transition initiatives of CAAC's FANS implementation plan[235] encompass ATM planning, system acquisition and equipment installation prior to 1996.[236] Most of China's ATM system acquisition before 1996 – either indigenously-produced or purchased from foreign original equipment manufacturers (OEM) – were independent procurements to satisfy specific ATM requirements. Typically, CAAC's regional bureaus or local airport authorities acquired these systems as independent, stand-alone units and service providers to meet local ATM needs. However, the ICAO-led emphasis on global ATM standards, seamless operation and open systems architecture reinforced the need for CAAC to develop a centrally-planned systems acquisition and integration philosophy.

Fifth Five-Year Plan (1976-1980). As early as 1975, well before China's economic reform and opening to the West, CAAC began the long process of relying on foreign support to develop China's national ATM system to meet modern standards.[237]

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[234] China's initial acquisition of sophisticated civil jet technology occurred during the Great Proletarian Cultural Revolution, an era of tremendous chaos, taking place largely at the expense of national education and training programs. The Chinese now refer to this period as the "ten years of turmoil" (shinian dongluan) or as the "period of tortuous progress" (quzhe qianjin shiqi). Its impact was particularly severe on China's education standards, particularly concerning science and technology. See Chen Shilu, Yan Hui, Cai Yuanli and Zhu, Xiaoping (Northwestern Polytechnical University), "The Historical Progress and Development of Space Technology and its Education in China" (conference paper), *International Astronautical Congress*, 7-11 October 1996, 12 p., and M.L. Spearman, "Some Observations on Chinese Education" (conference paper), *NASA Langley Research Center*, Hampton, VA (Design and Technology Meeting, Dayton, OH), 20-22 October 1986, 14 p.

[235] See "CAAC's Implementation Policy for CNS/ATM", *International Aviation*, July 1995, pp. 27-29.

[236] This includes all ATM planning and system acquisition that preceded the ninth five-year plan (1996-2000). For example, during the eighth five-year plan (1991-1995) China spent over $400 million to update its ATC systems. See "China to Invest in ATC Upgrades", *Flight International*, 15 May 1996.

[237] See "China Reviews Aerospace Requirements", *Aviation Week & Space Technology*, 2 June 1975, p. 279.

In fostering aviation infrastructure upgrades to complement its jet aircraft acquisitions,[238] China relied significantly on its existing relationships with Great Britain, France and Italy.[239] The U.S., which had a policy of containment regarding China, was forbidden to export aerospace hardware to China, principally because of its potential to support military operations. As a result, U.S. ATM equipment manufacturers were unable to contribute directly to CAAC's baseline ATM system. Early improvements, such as ATC and surveillance radar equipment upgrades at the Beijing and Shanghai international airports, largely benefited Great Britain, due to a combination of technical and political considerations.[240]

By 1979, in the early post-reform period and as the U.S. and China established diplomatic relations, China's progress in modernizing its ATM system began to subside as the practical challenges of relying on foreign sources to administer the sophisticated upgrade began to emerge.[241] These challenges included an absence of legal and trade agreements to protect foreign companies doing business in China[242]; ambiguous modernization priorities; uncertain international financing arrangements; and the impact of the technology gap on China's ability to absorb sophisticated modern systems.[243] These problems emerged as China came under increasing international and financial pressure to enhance its civil aviation infrastructure, accompanied by the prohibitive cost estimates of the need to modernize nearly all aspects of civil ATM simultaneously. CAAC's cost to meet ICAO standards at en route and terminal ATC facilities supporting Beijing, Shanghai and Guangzhou (Canton) alone were estimated at close to $100 million.[244]

In 1979, CAAC reportedly also consummated an unusual memorandum of understanding (MOU) with a U.S. consortium of aerospace companies; International Aviation Systems, Inc. – comprised of nine companies with varying ATC expertise – proposed to update the terminal control facilities and equipment at China's three international airports.[245] The government-approved MOU envisioned a two-phase

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[238] China's jet transport acquisitions in the early 1970's included 35 British Hawker-Siddeley Tridents, 10 Boeing 707-320C's and four Soviet Ilyushin IL-62's. See Rusty Shughart, "China's Civil Aviation Industry: Modernization, Technology Transfer and National Defense", *U.S. Air Force Institute for National Strategic Studies*, 1 October 1996, 211 pages.

[239] Throughout the 1960's, China and Great Britain sustained a cooperative relationship in civil aviation systems, to include aircraft as well as communication and navigation equipment. Much of the British motivation was to support its national civil aviation industrial base and to enhance the air safety and security standards of civil aviation operations among the peripheral regions of Hong Kong.

[240] The Plessey Company upgraded the Beijing (Shoudu/Capital) and Shanghai (Hongqiao) International Airports (the ILS equipment was developed by ITT's British affiliate, Standard Telephone & Cables, Ltd.). The 35 Tridents provided China the capability for Category 1 operations; some were reportedly also outfitted for Category 2 or 3 operation. Much of the British trade initiative was subsidized by the British government as part of export financing arrangements; the Sino-British Trade Council served as the focal point for this effort. See "China Reviews Aerospace Requirements", *Aviation Week & Space Technology*, 2 June 1975, p. 279.

[241] See Robert R. Ropelewski, "China's Aerospace Market Eyed Warily", *Aviation Week and Space Technology*, 11 June 1979.

[242] In 1979, the U.S. and Mainland China officially established diplomatic relations. In May, the two sides signed an agreement settling longstanding financial claims issues that dated from 1950. Following the creation of modern China in 1949, the U.S. froze $76.5 million worth of Chinese assets in the U.S.; China retaliated by confiscating nearly $200 million worth of U.S. property in China. The resolution of this issue provided the authority for China to receive "most-favored-nation" (MFN) trading status, reducing tariffs imposed on Chinese imports. The increase in the volume of trade between China and U.S. would generate the hard currency China required for international purchases; it also would improve the prospects for Export-Import Bank financing, opening the way for the efficient acquisition of high-cost civil aviation equipment, such as Boeing jetliners. Many analysts have referred to the "Ex-Im" Bank as the "Bank of Boeing." *Ibid.*

[243] *Ibid.*

[244] *Ibid.*

[245] *Ibid.* The consortium reportedly submitted its proposal in February 1978 (prior to diplomatic recognition), then updated it in March of 1979.

development effort. The first would address terminal control facilities; the second would address en route ATC equipment.

Sixth Five-Year Plan (1981-1985). During the sixth five-year plan, CAAC's urgency to address China's ATM shortcomings increased sharply. Two crashes and two hijackings within a year attracted increased media attention and criticism, domestic and international, of CAAC's performance and of China's national ATM system shortfalls.[246] At least part of the criticism focused on the lack of civil-military ATM coordination as some airline officials publicly criticized unreasonable flight profile limitations of civil aircraft operating in China's air space.[247]

In mid-1983, the Radio Technical Commission for Aeronautics (RTCA) conducted a fact-finding visit to China to investigate tangible CAAC programs to adopt and accelerate the ATM benefits from modern technology.[248] During the trip, the RTCA delegation visited several ATM locations around China, including the Beijing en route and terminal control center. Their findings indicated that CAAC's prioritized ATM upgrades were significant in each of the key categories of communication, navigation and surveillance. The systems CAAC had ordered or installed included French-made radar surveillance systems, U.S.-made stand-alone secondary radar units and hybrid systems with at least some Chinese-manufactured components.[249] The RTCA analysis was among the first and most comprehensive assessments of China's ATM situation by a Western organization. Its findings corroborated existing evidence that CAAC's ATM system procurements were isolated and independent acquisitions, often consummated as much for political reasons as for operational benefit or system integration capacity.

In 1985, China again expanded the scope of its ATM systems interest in hosting a national Aerospace Exhibition, the first of its kind in China. Myriad Western aerospace manufacturers and equipment suppliers participated in the exhibition, which addressed all aspects of the civil aviation industry, including airport construction, management and ATM infrastructure equipment. An ancillary by-product of the exhibition was the participation of the FAA Administrator, Donald D. Engen, who led an eight-member FAA delegation to offer China advice on ATC, safety standards and pilot training.[250] The impetus for the meeting stemmed largely from the agreement between China and

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[246] See Michael Wilkinson, "Chinese Airline Grapples with a Declining Image", *The Christian Science Monitor*, 14 June 1983, p. 9.

[247] An unnamed foreign airline official cited the danger and operational inefficiency of China's policy forbidding civil aircraft from flying above 30,000 feet to avoid clouds and turbulence. He added that the Chinese "invariably rejected" requests to fly above this level because of military traffic, citing the inflexibility itself as dangerous. He also indicated that civil air flights at 30,000 feet are much less economical that at 37,000 feet. *Ibid.*

[248] See Philip J. Klass, "CAAC Modernizes Its Air Traffic Control", *Aviation Week & and Space Technology*, 13 June 1983, p. 79.

[249] *Ibid.* This article is among the best describing China's early ATM situation. The article describes China's "basic air navigation system" as consisting of about 70 low-frequency nondirectional beacons built in China, plus approximately 18 VOR stations, some equipped with DME capabilities. About two-thirds of the VOR stations supported international routes into Shanghai, Beijing and Guangzhou (Canton) and provide service to points in eastern China; the rest supported an airway across the northern part of China for flights to and from cities such as Paris, Baghdad, Bucharest and Moscow. The article also notes that the distance separating VOR stations was as much as 300 miles, even along the key Beijing-Shanghai airway. Such continuous service was limited to aircraft flying above 20,000 feet; flights at lower altitude used NDB's. China's VOR/DME network is attributed directly to the ICAO-standard requirement to provide such navaids at airports serving foreign airlines; Thomson-CSF reportedly provided China most of its VOR's; the U.S. Northrop Wilcox Electric Division provided most of the DME's. China reportedly manufactured its own PAR's.

[250] See Jeff Bradley, "U.S. Federal Aviation Chief Discusses Safety With Chinese", *Associated Press*, 7 May 1985 and "Li Peng Meets U.S. Federal Aviation Administrator", *Xinhua New China News Agency*, 7 May 1985.

McDonnell Douglas to co-assemble MD-82 airliners in China.[251] A 14-member delegation of China's top aviation leaders, including the Minister of the PRC Ministry Aviation Industry (MAI) Mo Wenxiang, visited the U.S. in April to explore possibilities for further cooperation in the civil aircraft production industry.[252]

Seventh Five-Year Plan (1986-1990). Early in the seventh five-year plan, CAAC coordinated with the U.S. Department of Commerce, MAI and the China Council for the Promotion of International Trade (CCPIT) to co-sponsor the Aerospace Exhibition in Beijing, providing a forum for over 70 U.S. aerospace firms to present their products.[253] Among the ATC participants was Denro, Inc., which reportedly negotiated a joint agreement to co-produce its Model 400 air traffic communication systems.[254] The exhibition included FAA-CAAC discussions on a variety of ATM issues, including ATC training in the U.S. for CAAC personnel; training of CAAC and MAI personnel in airworthiness certification; and advice on long-term air traffic control system plans.[255] One FAA official reportedly noted that ongoing plans to decentralize CAAC would lead to ATM integration problems if each region were permitted to acquire its own ATC equipment in the future.[256]

In late-1985, China announced it would reorganize its decentralized CAAC along the administrative lines of the FAA, adopting Federal Aviation Regulation (FAR) aircraft design and certification standards.[257] The bilateral agreement provided the framework of cooperation between the FAA and CAAC on a wide variety of issues, including civil airliner airworthiness certification; training of ATC personnel; development of a national air space system plan for China; and training of air transport, maintenance and air crew flight standards inspectors.[258] Landmark studies funded by the U.S. Trade and Development Program (USTDP) led to additional recommendations on airport and ATC development in China, including ways to manage, coordinate and de-conflict civil and military air operations.[259]

USTDP sponsorship fostered CAAC's cooperation with the FAA to address the ATM complexities of China's military-civil air operations, particularly the poor coordination between military and civil flight organizations.[260] The FAA's comprehensive report recommended China standardize the utilization of military and civil ATC equipment;[261] improve flight coordination (particularly regarding "military

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[251] See Bruce Smith, "Douglas, China Sign MD-82 Co-production Agreement", *Aviation Week & Space Technology*, 22 April 1985, p. 31.
[252] See "McDonnell Douglas Hosts Visit of Top Aviation Leaders from People's Republic of China", *Business Wire*, 23 April 1985. MAI is now the Aviation Industries of China, or AVIC.
[253] See Donald E. Fink, Richard O'Lone and Craig Covault, "U.S. Presses for Stronger Role in Chinese Aerospace Market", *Aviation Week & Space Technology*, 19 May 1986, p. 18.
[254] *Ibid.*
[255] *Ibid.*
[256] *Ibid.*
[257] See "China Models Civil Aviation Administration on U.S. FAA", *Aviation Week & Space Technology*, 27 January 1986, p. 41.
[258] *Ibid.*
[259] *Ibid.*
[260] See Craig Covault, "China's Air Traffic Control System Hampered by Poor Coordination", *Aviation Week & Space Technology*, 12 October 1987.
[261] The military aircraft the Soviets supplied to China throughout the PLAAF's formative years contained "minimal and outdated" avionics suites, lacking sophisticated air intercept radars, radar warning receivers and enhanced navigation and communication equipment. See Jim Bussert, "PLAAF Avionic Technology and Upgrades", *Defense Electronics*, June 1990, p. 69.

transgressions"); enhance ATC coordination between civil and military ATC facilities; upgrade the ATC infrastructure (to include operational flight inspections); and improve separation minima, based on radar surveillance.[262] The report included interviews with Chen Xuhua, then-deputy chief of general dispatching for CAAC flight operations and future ATMB head. Chen reportedly stated that "Chinese officials have yet to recognize the necessity to improve the [ATC] system and that only a disaster, such as a midair collision, may precipitate action."[263]

Although CAAC was aware of the need to adopt a national, systems approach to address China's ATM challenges, its immediate goal, manifest in the aerospace fairs and their resultant equipment sales, was to address urgent ATM requirements. These practical requirements included the need to satisfy the ongoing expansion and growth of civil flight operations, consistently increasing over 20 percent annually. Initiatives such as the selection of Racal Communications, Ltd., to furnish HF transmitters to provide meteorological broadcasts for airlines and airports addressed existing exigencies, at the expense of long-term planning.[264]

However, the interests of MAI and CAAC coincided with those of the FAA concerning support for China's indigenous aircraft production program, for which China sought FAA airworthiness certification for export. Unlike ATM, where the FAA's participation was limited to program analysis and recommendation, the technical standards of FAA airworthiness certification required China to adhere to design and performance criteria. The certification process required China to satisfy scientific standards for its export aircraft. For example, the Hong Kong Aircraft Engineering Company (HAECO) refurbished two China-manufacturer transports (the Yun-7 and Yun-12) with modern Western avionics.[265] One upgrade program resulted in the production of 55 Yun-7-100's at Xi'an over the span of five years. The avionics included radios and navigation units; compasses; altitude references; color radar; and VLF/Omega navigation systems.[266] HAECO's other avionics program called for the production of 24 Yun-12 transports with Collins avionics at the Harbin Aircraft Corporation.[267]

Initiatives Since the Seventh Five-Year Plan. Beginning with the eighth five-year plan, CAAC began to reassert its leadership over the development of China's ATM infrastructure. This was in part due to its continued involvement with the FAA on civil aircraft certification, both co-assembly and export products. In addition, Western companies intensified their efforts to upgrade China's ATM infrastructure and training in accordance with emerging standards from ICAO.

Eighth Five-Year Plan (1991-1995). In mid-1990, CAAC announced the major ATM initiatives of the eighth five-year plan, the most comprehensive ever revealed in

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[262] See Craig Covault, "China's Air Traffic Control System Hampered by Poor Coordination", *Aviation Week & Space Technology*, 12 October 1987.
[263] *Ibid.*
[264] CAAC installed the 10-kilowatt HF transmitters at the Beijing airport in an effort to expand civil aviation. See "Filter Center", *Aviation Week & Space Technology*, 12 October 1987, p. 157.
[265] See Jim Bussert, "PLAAF Avionic Technology and Upgrades", *Defense Electronics*, June 1990, p. 69.
[266] *Ibid.*
[267] *Ibid.*

China.[268] First, Zhuang Liang, a member of CAAC's Flight Operation Department, noted that China would create a new ATC center at Sanya, Hainan.[269] The facility would be equipped with a VOR station to assist civil air navigation within a 200-nautical-mile communication range. Second, Zhuang stated that China would install an additional 70 VOR stations to support CAAC's 320 air routes, augmenting the 40 VOR-equipped stations installed on international and major domestic air routes. Zhuang described the VOR as "usually unaffected by natural conditions" and able to "provide accurate and stable information to jetliners."[270] Third, Zhuang noted that CAAC would augment China's network of 13 radar stations with 11 additional sites by 1992, and that it would expand the installation of advanced ILS support systems at China's airports, specifically those which frequently experience inclement weather.[271] Zhuang noted that China had installed ILS equipment at 25 civil airfields, importing 15 systems and manufacturing the remainder indigenously.[272] Fourth, Zhuang reported that CAAC would establish a satellite communication network "within a few years."[273]

The four-phase enhancement program of the eighth five-year plan was China's initial attempt to adopt and resource national ATM infrastructural improvements based on system interconnectivity and compatibility. By the end of the eighth five-year plan, China reportedly spent over 30 billion yuan ($3.7 billion) on airport construction and upgrades to its ATC system and other facilities.[274] Approximately 3.5 billion yuan ($430 million) was invested in ATC systems during the five-year period.[275] During this phase of China's ATM development, CAAC and the FAA also concluded a bilateral agreement on the recognition of the airworthiness of its civil aircraft and supporting air products.[276] The agreement stemmed largely from the State Council's issuance of domestic airworthiness regulations in 1987 and formed the basis for further cooperation between CAAC and the FAA in the fields of aviation security, ATC and bilateral trade in aviation products.[277]

CAAC also intensified its acquisition of products and training services from foreign firms during the eighth five-year plan. In 1994, it signed a $63 million contract with Alenia (Italy) for 15 ATC radar systems; the contract was a follow-on to an agreement in 1989 for Alenia to supply another 15 radar systems, which became fully

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[268] See "CAAC to Update Navigation Systems", *Xinhua New China News Agency*, 21 April 1990.

[269] China had announced its intent to create the Sanya facility as early as 1988. Xu Xiyao, Director of CAAC's Flight Operation Bureau reported that a "major" ATC center at Sanya would serve international flights over the South China Sea, providing radar, meteorological and navigation data to high and low altitude flights over the Xisha (Paracel) Islands; Xu added that China would create a similar center on the Xisha islands to cover the air space over the Nansha Islands. The Sanya facility would be part of China's national effort to help ICAO open a second major air route linking Europe and Asia; the new route would cross Hainan Island, shortening the trip from Bangkok to Hong Kong and Tokyo. See "Air Traffic Control Center Planned", *Xinhua New China News Agency*, 10 June 1988.

[270] *Ibid.*

[271] *Ibid.* Zhuang noted that the ILS will support civil airliner landings with visibility at 400 meters.

[272] *Ibid.*

[273] *Ibid.* The SATCOM announcement was significant as China's first announced initiative to implement a satellite-based CNS/ATM system.

[274] See "China's Air Transport Industry Developing Fast", *Xinhua News Agency*, 29 September 1995.

[275] See "China to Invest in ATC Updates", *Flight International*, 15 May 1996 and Renee Schoof, "China Improving Dozens of Airports to Boost Growth, Safety", *The Associated Press*, 7 April 1995.

[276] See "China, U.S. Sign Bilateral Agreement on Airworthiness", *Xinhua General Overseas News Service*, 15 October 1991.

[277] *Ibid.*

operational by the end of 1994.[278] In 1993, Alenia, which has been active in China since the 1970's, estimated the value of China's ATC market at $2 billion for the 1990's alone.[279] In 1995, Boeing expanded its relationship with China by initiating ATC-related training. Boeing provided the Civil Aviation Flying College (CAFC) with two Boeing 737 simulators, part of its program to train over 200 pilots; Boeing also joined CAAC in training Chinese air traffic controllers in English phraseology, radar procedures, and ground control methodology.[280]

Ninth Five-Year Plan (1996-2000). As China prepared its ninth five-year plan, CAAC intensified its effort to develop a national ATM architecture with globally compatible and interoperable support systems. The challenges and opportunities ICAO's global ATM planning and development initiatives presented to China served as a major external force for this endeavor. In January 1994, largely in response to China's disastrous civil air safety and security performance of 1993, CAAC, Boeing, the Harris Air Traffic Control Systems Division and the Washington Consulting Group formed a joint task force to address the China's national ATM architecture.[281] The task force produced a series of measures to apply to two major aspects of the ATM issue. The first set included initiatives to immediately improve the air safety and system capacity of China's civil aviation;[282] the second set included the development of a CNS/ATM transition plan for China.[283]

One of the major accomplishments of the joint task force was its detailed review of CAAC's satellite-based CNS/ATM plans in light of ICAO's refined, globally-coordinated standards. Senior CAAC managers reportedly authorized the task force to develop detailed plans for the implementation of the internationally accepted FANS doctrine as the foundation for China's future ATM system.[284] The group reportedly also investigated other ATM infrastructure policy initiatives, including an initial examination of a national air space management plan and the possible creation of an air navigation technical center.[285]

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[278] See "Aerospace in China", *Business China*, 28 November 1994. The Alenia ATC equipment sale formed the second part of the two-part "Marco Polo" project, designed to help China overcome ATC coordination problems with many of its neighbors. In 1991, the Marco Polo 1 project initiated the installation of 15 Alenia radar systems; the last became operational at the end of 1994. Marco Polo 1 provided coverage for most of China's coastal areas. Marco Polo 2 envisaged the supply and installation of six ATC centers to optimize traffic on routes used by airlines with links to Europe, South Asia and North America. See "An Eye to the Skies", *China Economic Review*, February 1995, p. 19.

[279] See Michael Mecham, "Asian ATC Sparks Intense Competition", *Aviation Week & Space Technology*, 5 April 1993, p. 50. In 1992, Alenia formed a 20-year joint venture with two organizations (the RIDA Industrial Group and Dragon Base Investment, Ltd.) to manufacture primary and secondary radars, as well as data display consoles, computers and communication networks. The primary goals pf the Saphire International ATC Engineering Co. Ltd., are to manufacture ATC equipment, carry out related research and develop ATC markets in Asia and other parts of the world. See "Joint Venture of Airport Control Equipment Set Up", *Xinhua New China News Agency*, 25 February 1992.

[280] See "Boeing Expands Support Commitment in China, Says 777 will be Delivered in '95", *Asian Aviation News*, 15 December 1995.

[281] A Boeing engineer served as the task force leader and director; ATMB director Chen Xuhua served as the deputy. See Paul Proctor, "Joint Effort Targets Chinese Air Safety", *Aviation Week & Space Technology*, 8 August 1994, p. 50.

[282] These "near-term solutions" included 16 independent actions to address civil aviation along the "golden triangle" routes of Beijing-Shanghai-Guangzhou (Canton). The task force determined that the air traffic in this region was nearing system capacity and that the air support system would be unable to meet the demands of projected growth. *Ibid.*

[283] These national policy initiatives included air space management issues as well as theoretical and practical FANS planning. *Ibid.*

[284] *Ibid.*

[285] *Ibid.*

The joint task force, which coincided with CAAC Minister Chen Guangyi's renewed emphasis on professionalism and responsibility based on domestic and international legal tenets, prompted CAAC to adopt a global perspective towards China's domestic ATM development. In 1995, Li Jun, director of CAAC's planning department, noted that China was "starting a very important project to transform air traffic control, telecommunication, navigation and meteorology facilities."[286] He added that CAAC would institute a civil air radar system for the heavily populated areas of eastern China and adopt a satellite-based navigation system. Li also stated that by the year 2000, all of China's major routes would have radar and advanced navigation equipment, including satellite-based systems; he estimated that over 70 percent of China's airports would have advanced weather-forecasting equipment.[287]

Minister Chen, speaking at the second meeting of the National Scientific and Technological Conference for the Civil Aviation Industry, acknowledged the importance of technical competency in addressing China's ATM transition to global standards.[288] He noted that "scientific and technological standards have become a key factor in aviation security, service, economic efficiency and every other aspect of the industry."[289] Shen Yuankang, CAAC deputy director, related the issue of technical competency directly to ATM, noting that CAAC would implement a new air navigation system, establishing radar control and VHF coverage in eastern China and ADS monitoring in the west.[290]

Chen, announcing CAAC's ATM goals for the ninth five-year plan, stated that China would increase its investment in civil airports and civil air infrastructure while continuing to limit the number of new aircraft acquisitions.[291] He noted that in 1995, China procured only 21 new aircraft and retired 11 older models; the increase in the commercial air fleet reportedly was the smallest of the eighth five-year plan.[292] In announcing the ATM goals for China's ninth five-year plan, CAAC deputy director Bao Peide reported that China would spend $722 million to update its ATM system.[293] CAAC reportedly will devote nearly $670 million – the vast majority of this investment – to implement full radar coverage for China's three main airports: Beijing, Shanghai and Guangzhou (Canton); CAAC intends to invest the remaining $53 million on projects supporting CNS/ATM compatibility.[294]

ATM Research, Development and Acquisition Initiatives. Although CAAC relies principally on foreign manufacturers and technical training sources for most of its ATM system procurement, it also coordinates the activities of a wide variety of ATM research, development and acquisition organizations. Much of this effort is accomplished with the

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[286] See Renee Schoof, "China Improving Dozens of Airports to Boost Growth, Safety", *The Associated Press*, 7 April 1995.
[287] *Ibid.*
[288] See "China Sets Strategy for Civil Aviation Technological Progress", *Xinhua New China News Agency*, 8 August 1995.
[289] *Ibid.*
[290] *Ibid.*
[291] See Tony Walker, "Airport spending in China to increase in new five-year plan", *The Financial Post*, 8 February 1996, p. 61.
[292] Li Zhao, CAAC Vice-Minister, noted that China would reconstruct 40 of its 132 airports during the ninth five-year plan; the central government will pay a third of the cost of airport reconstruction, with the remainder coming from local governments and foreign investors. The government's outlays for airport investment to the year 2000 reportedly was about three times the amount it invested in the eighth five-year plan. *Ibid.*
[293] See "China to Invest in ATC Updates", *Flight International*, 15 May 1996.
[294] *Ibid.* Also, See Paul Lewis, "The Long March", *Flight International*, 6 November 1996, and Zhang Xingwang, "The Approach of Some Problems in the Management of Communication and Navigation", *Air Traffic Management*, June 1997, pp. 40-42.

assistance of the Aviation Industries of China (AVIC) and the Ministry of Electronics Industry (MEI).

Research Community. China oversees a vast and growing network of academic organizations that engage in theoretical and applied research and development related to ATM. These efforts yield both military and civilian applications. Often, research at the university level is accompanied by the participatory involvement of China's ministries, which also underwrite applied research and development projects.[295]

Regionally, Nanjing is China's primary center for electronics research. The Nanjing Research Institute of Electronics Technology conducts advanced radar research, while the Electronic Devices Research Institute develops supporting microelectronic equipment.[296] The work performed at these institutes augments the applied research of the Nanjing University of Aeronautics and Astronautics (NUAA).[297] The ATM portion of this effort includes the official government participation of the 28th Institute, subordinate to the Ministry of Electronics Industry (MEI).

China also has a robust ATM research and development effort in Xi'an – a more remote area where the lower density of air traffic permits greater navigation flexibility to support ATM testing and evaluation. The Northwestern Polytechnical University (NPU) is a leading aviation research center.[298] Its efforts, combined with the Xi'an Research Institute of Navigation Technology (RINT) and the China Flight Test Establishment (CFTE)[299] directly support the government initiatives sponsored by the 20th Institute, another MEI organization. The 20th Institute is China's leading center for applied testing of Global Navigation Satellite System (GNSS) technologies.

Other regions of China occasionally conduct research peripherally related to ATM.[300] However, China's limited ATM research and development resources are generally centralized at a few key locations, often to take advantage of related research and development programs and initiatives.

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[295] The Aviation Industries of China (AVIC) (formerly, the Ministry of Aviation Industry, or MAI) and the Ministry of Electronics Industry (MEI) are the principal government organizations that outline and foster university applied research and development projects to support the civil aviation industry.

[296] See James C. Bussert, "Chinese Modernization Aids Air Defense Radar, Missiles", *Signal*, July 1994, p. 63.

[297] Since 1991, the Nanjing University of Aeronautics and Astronautics (NUAA) has a special administrative relationship with CAAC and the China Aviation Industrial Corporation (CAIC). These two organizations jointly administrate NUAA as a means of developing it into a key center to meet the needs of China's aviation production and air services industry. CAIC administered NUAA until CAAC's participation in 1991; in 1993, CAIC and CAAC have jointly managed NUAA's Civil Aviation College, training a large number of specialists in the fields of ATC, air transport management and aircraft maintenance engineering. See "CAAC and CAIC Jointly Administrate University", *Xinhua New China News Agency*, 25 March 1995.

[298] The Beijing University of Aeronautics and Astronautics (BUAA) is the Northwestern Polytechnical University's primary counterpart. However, BUAA does not offer the vast array of applied research opportunities available at Xi'an, which is also China's leading space research center.

[299] The China Flight Test Establishment (CFTE), located at Yanliang (near Xi'an and the Xi'an Aircraft Company), conducts applied flight tests of advanced civil and military ATM technologies. Since 1989, it reportedly has operated a test pilot training school to evaluate programs at CFTE and aircraft development factories around China; CFTE also designs, develops and produces a variety of specialized avionics. Its program initiatives include the upgraded Yun-7- 200B and the Yun-8 military transport, which it tested as early as 1991 with avionics supplied by Rockwell Collins. See "First Chinese Test Pilots Graduate", *Flight International*, 23 October 1991 and "Pressurized Y-8 Undergoes Tests", *Flight International*, 23 October 1991.

[300] See Liu Jiyu, Li Deren and Chen Xiaoming, "GPS Photogammetric Mapping in China" (conference paper, in English), *International Astronautical Congress*, 6-9 October 1997. This paper describes research conducted at the Wuhan Technical University of Surveying and Mapping since June 1990 using GPS to create terrain maps for photogrammetric mapping of boundary areas between China and Vietnam and of Hainan Island.

CNS/ATM Applied Research in China

Selected Samples of Published Research

Indigenous CNS/ATM Research:

Communication:

"Implementation of VHF Data Link for Civil Aviation in China" (conference paper, in English), Fan Weibing and Zhang Jun (Beijing University of Aeronautics and Astronautics), Tian Zhengcai and Bi Xin'an (Civil Aviation Administration of China), *Position, Location and Navigation Symposium, Institute of Electrical and Electronics Engineers*, Atlanta, GA, 22-26 April 1996.

"Primary Analysis of the Development Approach to Chinese Satellite Mobile Communications", Tong Kai and Guo Jianning, *AAIA Technical Library*, 1995, 19 p.

"The Message Processing Techniques on VHF Data Link", Lu Boying and Zhu Qiling (Beijing University of Aeronautics and Astronautics), *Pacific International Conference on Aerospace Science and Technology*, National Cheng Kung University, Tainan, Taiwan, 6-9 December 1993, Volume 1, pp. 525-527.

"The Beijing Inmarsat's TT&C System", Lin Rongle, *Aerospace China*, July 1992, pp. 41-45.

Navigation:

"On Analyzing System Transformation Errors Related to a Differential GPS Reference Station", Li Yong, Yuan Jianping and An Ning, *Journal of the Northwestern Polytechnical University*, August 1997, pp. 466-470.

"A Very Low Cost Method for Midcourse Guidance of a Type of Chinese Antiship Missile Using GPS Signals", Min Changwan, Yuan Jianping and Jia Huamin, *Journal of the Northwestern Polytechnical University*, August 1997, pp. 471-475.

"GPS Multi-vehicle Positioning with a Single Receiver", Wei Gao and Xu Jiaodong, *Journal of the Northwestern Polytechnical University*, November 1996, pp. 531-534.

"Design and Implementation of a Navigation System for Pilotless Aircraft Using GPS", Wang Yongsheng, Li Xiangpeng and Jia Huamin Northwestern Polytechnical University), *Journal of the Northwestern Polytechnical University*, August 1996, pp. 480-484.

"DGPS-based Aircraft Flight Guidance/Test System" (conference paper, in English), Jia Huamin, Yuan Jianping, Dou Xiaomu (Northwestern Polytechnical University) and Guo Pingfan (China Flight Test Establishment), *International Conference on GPS*, Taipei, Taiwan, 12-15 June 1996.

"Global Positioning System: Past and Future Applications", Yuan Jianping, *AIAA Technical Library*, 1996, 19 p.

"Long Range Differential GPS and the Concepts of Chinese Plans to Establish Broad Area Networks", Lu Guohua and Liu Yanli, *AIAA Technical Library*, 1996, 26 p.

"Synchronous Satellite Navigation on Large Regions of the Earth's Surface and in Near Earth Space", Zhong Xiaojun, et al., *AIAA Technical Library*, 1995, 32 p.

"On Suitable Relaxation of Limitation of +/- 1 Chip for GPS Utilization in China", An Dong, Ren Sicong and Zheng E. (Northwestern Polytechnical University), *Northwestern Polytechnical University Journal*, 3 August 1994, pp. 402-406.

"Experimental DGPS Landing System Made in China", Yang Peixia, *International Aviation*, July 1993, pp. 52-53.

"GPS Flight Test on the Y-8 Aircraft", Zhai Zhengzhi, *International Aviation*, January 1993, pp. 50-51.

"GPS Used for Pesticide Spraying in Beijing", Wang Renlin and Xu Shenghua, *International Aviation*, June 1992, pp. 21-22.

Surveillance:

"Research and Development on an Automatic Dependent Surveillance (ADS) System", Lu Boying, Zhang Jun, Tian Zhencai and Tang Zhengyou, *Beijing University Journal of Aeronautics and Astronautics*, April 1997, pp. 147-151.

"A Review of Chinese Designed Surveillance Radars - Past, Present and Future" (conference paper), Li, Nengjing (Chinese Institute of Electronics), IEEE International Radar Conference, Alexandria, VA, 8-11 May 1995.

"ADS System Implementation Study, Automatic Dependent Surveillance" (conference paper), Lu, Boying and Zhu, Qiling (Beijing University of Aeronautics and Astronautics), Pacific International Conference on Aerospace Science and Technology, National Cheng Kung University, Taiwan, 6-9 December 1993.

ATM:

"A New C-Band Doppler Weather Radar System in China" (conference paper, in English), Ge Wenzhong, Ye Panxi, Zhang Xueru, Gao Zhonghui and Zhao Jun, *27th Conference on Radar Meteorology*, American Meteorological Society, Vail, CO, 8-13 October 1995.

Foreign-Assisted, Collaborative CNS/ATM Research:

Communication:

"VHF A/G Data Link in China", Bi Xin'an, Zhang Jun, Fan Weibing and Lu Boying, *International Aviation*, December 1995, pp. 35-36.

Navigation:

"Air China Completed GPS/ACARS Demonstration Flight", Chen Hengbao, *International Aviation*, January 1998, pp. 57-59.

Surveillance:

"ADS Flight Test in Beijing Capital Airport", Lu Xiaoping and Liu Jinhua, *International Aviation*, November 1997, pp. 27-28.

ATM:

"CNS/ATM Demonstration in Xi'an", Zhang Ting, *International Aviation*, May 1996, pp. 56-57.

"CNS/ATM in China – Developing a Path to the Future" (conference paper, in English), Qiu Zhihe (Xi'an Research Institute of Navigation Technology), John Estill and Steven Hammond (Rockwell International Corporation), *Proceedings of the Institute of Navigation – National Technical Meeting*, Santa Clara, CA, 22-24 January 1996.

Applied Research and Development. China's ATM research and development agenda includes theoretical and applied initiatives.[301] The research itself can be independent or collaborative ventures, either domestic or international products. The table on pages 56-57 summarizes recent research and development interests and products. Some ATM research in China is clearly weapon-related, particularly in investigating and testing the application of GNSS technology to advanced air navigation.[302]

Equipment Acquisition and Co-Production Initiatives. China has only a limited capability to indigenously produce modern ATM systems. Of specific complexity to China is the challenge of its domestic electronics industry to design and field compatible systems of open-ended architecture. Not much is known about China's specific ATM production processes, although the traditional military emphasis on electronics applications may be of ancillary civil benefit. China has proven in its space program that it has the national capacity for programs of exceeding technical complexity. However, a national focus is absent in the development of China's ATM system.[303] The table on pages 59-61 outlines at least part of China's known CNS/ATM acquisition initiatives, indigenously produced and imported. In addition, since 1997 CAAC has hosted an international technology fair for CNS/ATM equipment.[304] This exhibition serves as the venue for domestic and foreign CNS/ATM vendors to advertise and display their equipment and offer their ATM services.

China's CNS/ATM Transition Schedule. CAAC has published China's CNS/ATM transition schedule for mid-term and long-term projects (see page 63). China has been involved with ICAO's CNS/ATM initiative from an early stage, serving as a founding member of the Pacific Engineering Trials (PET) and an actively participating in ICAO's Asia/Pacific Air Navigation Planning and Implementation Regional Group (APANPIRG).[305] China formally endorsed the adoption of CNS/ATM at ICAO's 31st Assembly. Its policy broadly calls for the use of a range of systems, including automatic dependence surveillance (ADS); the global navigation satellite system (GNSS) for en

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[301] In 1994, an open source periodical reported that an unnamed Chinese research organization, likely with the support of Xi'an, was developing a twin-satellite "constellation" to provide rudimentary air navigation services. The Twin Star project, which China reportedly would launch in 1998, would provide navigation fixes within 20 meters (66 feet). No other references to Twin Star have appeared in the open media. See "Chinese 'GPS' Project Set", *Aviation Week & Space Technology*, 17 October 1994, p. 25.

[302] See Min Changwan, Yuan Jianping and Jia Huamin, "A Very Low Cost Method for Midcourse Guidance of a Type of Chinese Antiship Missile Using GPS Signals", *Journal of the Northwestern Polytechnical University*, August 1997, pp. 471-475, and Wei Gao and Xu Jiaodong, "GPS Multi-vehicle Positioning with a Single Receiver", *Journal of the Northwestern Polytechnical University*, November 1996, pp. 531-534, and Wang Yongsheng, Li Xianpeng and Jia Huamin, "Design and Implementation of a Navigation System for Pilotless Aircraft Using GPS", *Journal of the Northwestern Polytechnical University*, August 1996, pp. 480-484. The military application of advanced navigation technology was a major concern of the JDCC ATC initiative with China, terminated in 1996 in part due to its sensitive political-military implications. See Robert Butler and Rusty Shughart, "The Air Traffic Control (ATC) Initiative: A Case Study in U.S. Decision-making and U.S.-China Relations", *U.S. Air Force Institute for National Security Studies*, (forthcoming).

[303] China has been successful in developing ATM equipment on a much smaller scale. In 1994, China announced that the China Civil Aviation Flying College and Sichuan University jointly developed an ATC radar simulator system to enhance air traffic controller training. The DRS-93 reportedly is comprised of a large computer image and graphics simulating system that has incorporated the advanced international technologies in the field. CAAC deputy director Li Zhao noted that by the year 2000 the number of air traffic controllers in China would increase from 1,400 to about 5,000. He added that CAAC has an urgent demand for advanced training facilities and that the DRS-93 was installed at several of China's major ATC centers and centers and civil aviation colleges. See "China Develops Air Traffic Control Radar Simulator", *Xinhua New China News Agency*, 22 December 1994.

[304] The initial iteration of the CAAC-organized exhibition took place at the Military Museum of China (Beijing) from 16-19 October 1997; the second occurred from 6-9 May 1998.

[305] See Peter L. Massoglia and Robert D. Till, "Automatic Dependent Surveillance (ADS) Pacific Engineering Trials (PET)" (conference paper), *IEEE PLANS '92 - Position Location and Navigation Symposium*, Monterey, CA, 24-27 March 1992.

China's Acquisition of CNS/ATM Equipment

I. Indigenously-produced Equipment:

Surveillance:

Airport/Airfield Surveillance Radar (ASR)	REL-1 ASR: L-band radar; can provide guidance up to a range of 230 km; targets can be detected up to a maximum range of 400 km. National export product, China National Electronics Import and Export Corporation (CNEIEC).
Secondary Surveillance Radar (SSR)	Type 681 SSR: solid-state device, with exception of the single transmitter tube; transmitter operates on four interrogating modes, A, B, C and D plus a test mode; national export product, CNEIEC.

ATC:

Precision Approach Radar (PAR)	Type 793 PAR: an integrated air surveillance and approach radar to control air traffic in terminal areas; range is approximately 100 km for a small aircraft in normal weather conditions; national export product, CNEIEC.

Meteorological Systems:

Wind-finding Radar	Type 701.
Weather Radar	Type 711: mobile or fixed weather radar system operating in X-band; used for general detection of dense cloud and precipitation; national export product, CNEIEC.
	Type 713: fixed, high power radar operating in C-band; designed to detect precipitation and warning of storms; national export product, CNEIEC.
	Type 714: modern S-band equipment for the detection and location of precipitation; national export product, CNEIEC.

II. Imported Equipment:

Communication:

Voice Communications Switching System (VCSS)	Denro Inc (US): Model 400D to Zhuhai Airport; Model 400 VCSS has been operational at Guangzhou ACC since 1985.
Communications Recorders (ATC)	Dictaphone Corporation (US)
Communication Systems	OTE SpA (Italy)
	Rohde & Schwarz (Germany): communication equipment to 14 airports.

Navigation:

Distance Measuring Equipment (DME)	Alcatel Air Navigation Systems Italia (Italy)
	Pelorus Navigation Systems (Canada)

	Wilcox Systems (US): seven systems (see ILS, below)
Doppler VHF Omnidirectional Radio Range (DVOR) systems	Airport Systems, International (US)
Instrument Landing Systems (ILS)	Nauvia Systems (formerly, Normarc) (Norway): a contract with China National Instruments Import and Export Corporation for delivery of 24 ILS systems to airports, including four for Beijing and Shanghai Airports.
	Wilcox Electric (US): seven Mark 10 ILS and seven DME's for Linzhou, Yanzhi, Anqing, Wozhou, Dayang, Lading and Shijiazhuang Airports; CAT II ILS at Beijing Capital Airport.
Non-directional Beacons (NDB)	Nautel (Canada)
	Racal Avionics (UK)
Miscellaneous Navigation Aids	AWA (formerly AWADI) Aerospace/Interscan (Australia): navaids to 70 locations. The first seven navaids are being supplied from Australia; the remainder being assembled in Tianjin under a technology transfer agreement. An MLS was sold by Interscan (now part of AWA) to RINT in X'ian in 1972.
Surveillance:	
Monopulse Secondary Surveillance Radar (MSSR)	Raytheon Cossor (formerly Cossor) (UK)
ATC Systems:	
ATC Center	Alenia Difesa (Italy): turnkey ATC center, including advanced radar sensors, communications and flight management system at Wuhan; primary radar at Shenzhen and ATC work at 13 other airports.
Integrated Systems	Northrop-Grumman ESSD (US): ASR-9 and MSSR radars and VCCS.
	Raytheon (Canada): ATC radar systems
	Telephonics Corp (US): AeroTrac ATMS at terminal control center, Zhuhai ACC, Guangzhou.
	Toshiba (Japan): ATC systems and displays.
	Siemens Plessey Systems (Airsys ATM) (UK): contract worth over $28 million to supply radar and associated systems.
Miscellaneous:	
ATC Display	RMSL Traffic System Inc (Canada)
Meteorlogical System	Artais Weather-Check, Inc. (US): Automated Weather Observing System (AWOS)
	Enterprise Electronic Corporation (US): Doppler weather radar
	Impulsphysik Jenoptik (Germany): AWOS
	Vaisala Oy (Finland): AWOS

Airfield Lights	ADB (Belgium)
	DeVore Aviation (US): pulsed light approach slope indicators (PLASI)
	THORN Airfield Group (France)
Visual Tower Simulator	ATC Aerospace, Inc. (Canada)

Primary Information Sources: (1) David Rider, Jane's Air Traffic Control (annual publication: 1992-93; 93-94; 96-97; 97-98), *Jane's Information Group*; and Martin Streetly, Jane's Radar and Electronic Warfare Systems, 1997-98, *Jane's Information Group*, 1997.

Note: the equipment listed above does not include China's military tactical aviation systems.

route navigation, non-precision, and possibly Category I, approaches; and satellite communication for voice and radar data communication, supplemented by VHF.

Administratively, CAAC's ATMB oversees the activities of the CNS/ATM steering committee, implementation office and advisory group.[306] However, China has not yet devised a definitive FANS transition timetable with institutional milestones. Lu Xiaoping, a principal CAAC CNS/ATM authority, is reportedly responsible for overseeing the coordination of a more detailed implementation program.[307]

Generally, CAAC[308] has developed and presented its program objectives for the mid-term of the FANS transition plan, which it has designed to coincide with the ninth five-year plan (1996-2000). These general objectives are five-fold, as follows:[309]

1. improve the levels of ATM services
2. upgrade to international standards.
3. ensure air traffic safety.
4. accelerate air traffic flow.
5. meet the requirements of ICAO FANS.

In addition to these general goals, CAAC has devised six specific technical objectives for the mid-term of the FANS transition plan:[310]

1. expand the range of control and reduce the number of ATC units.
2. realize radar control over the middle and eastern parts of China.[311]
3. establish VHF data link operations over China's main routes.
4. achieve automated dependent surveillance (ADS) over the main routes of western China.
5. adopt satellite technology in the western and northeastern parts of China.
6. trial new CNS/ATM technologies and engineering, such as VHF data link (VHF DL), ADS, and GNSS, including Wide-Area Augmentation Systems (WAAS).

Communication. To support the development of future air communication, China intends to:[312]

1. introduce satellite communication to first provide at least voice and data communication; in the extreme areas, CAAC will maintain HF communication until SATCOM coverage is readily available.
2. maintain and develop VHF communication for voice and certain data

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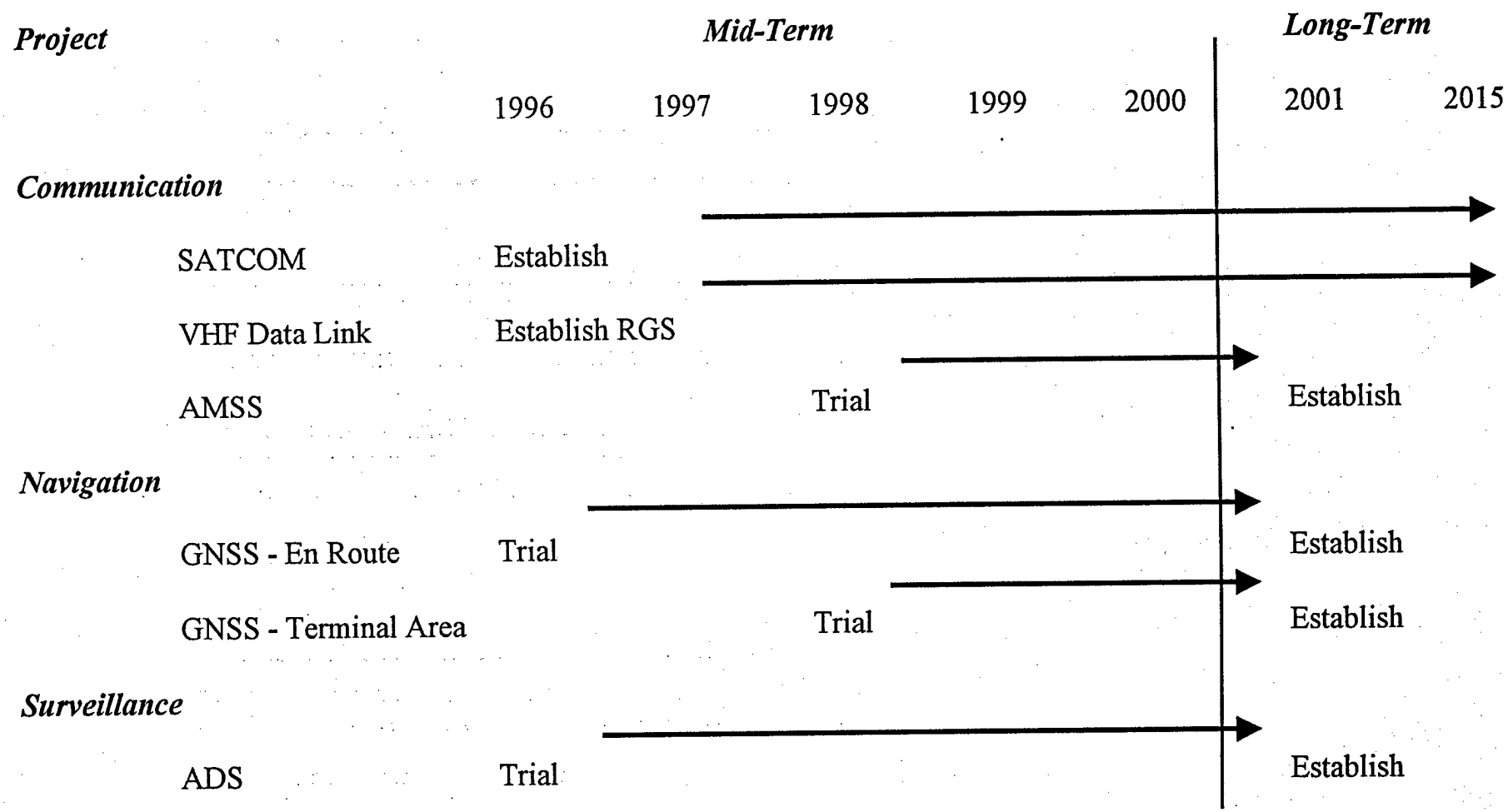
[306] See CAAC joint manuscript, "CAAC's Implementation Policy for CNS/ATM", *International Aviation*, July 1995, p. 27 (further outlined in Chapter 2).
[307] See Paul Lewis, "The Long March", *Flight International*, 6 November 1996.
[308] Specifically, the Division of Technical Development, subordinate to the ATMB, oversees CAAC's three-phase CNS/ATM transition plan.
[309] See CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the JDCC (1996).
[310] *Ibid.*
[311] Such high altitude coverage with occur at and above Flight Level 7,000, or 7,000 meters above sea level.
[312] See Zhou Qihuan, "The Evolutionary Change of the Air Traffic Environment", *International Aviation*, October 1995, p. 5.

China's CNS/ATM Transition Schedule



links, mostly for continental and terminal areas.

3. use the S mode SSR data link, particularly in high-density air traffic air space and terminal areas to provide air traffic services (ATS).

4. establish an Aeronautical Telecommunication Network (ATN) to merge air-to-ground data communication and terrestrial data communication into a coherent network. After networking SATCOM, VHF data link (VDL) and S Mode SSR sub-networks, it will be possible for CAAC to carry out the high-speed exchange of data between relevant computer systems.

CAAC has a phased, three-part agenda to prepare China's civil air communication resources and sub-systems to transition to the global CNS/ATM standards: adoption of a satellite communication system, creation of a VHF data link and implementation of a system of aeronautical mobile satellite services (AMSS).[313]

Satellite Communication System. In 1996, CAAC announced the activation of its satellite communication (SATCOM) network, a system it designed to improve safety and ease dependence on conventional landline telephones.[314] The ground-to-ground system consists of very small aperture terminal (VSAT) sites at all 97 civil airports, supporting more than 2,600 data and communication terminals.[315] The system, reportedly costing over 210 million yuan ($25 million), is comprised of earth stations and equipment of the Hughes Corporation. ATMB Director Chen Xuhua reported that the network would "greatly improve the communication conditions for air traffic management, and further guarantee the safety of flights."[316] CAAC initially activated the SATCOM telephone earth stations (TES); construction of the accompanying digital personal exchange system (PES) was expected to be complete by the end of 1996.[317] CAAC officials reported that China would use the AsiaSat 1 satellite for direct ATC telephone calls, sharing of radar and meteorological data and telephone conferences.[318] Chen noted that China's central government had invested significantly in civil aviation infrastructure "in a bid to catch up with the rapid growth of the country's air

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[313] See CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the JDCC (1996).

[314] See "Satellite Communications Network Opened for CAAC", *Xinhua New China News Agency*, 29 April 1996 and "China - Satellite Network Launched For Aviation", *Newsbytes*, 28 May 1996. Prior to creating its satellite communication system, CAAC had to rely on landline telephone services provided by China's Ministry of Posts and Telecommunication (MPT).

[315] During a demonstration of the system in Beijing, CAAC officials successfully contacted by telephone stations at Guangzhou (Canton), Shanghai, Haikou, Harbin, Urumqi, and Lhasa (Lasa) airports, as well as foreign ATC centers in Mongolia (Ulan Bator), Nepal (Katmandu) and Mianmar/Burma (Rangoon), reportedly also part of the CAAC network. *Ibid.*

[316] A VSAT network supports the two-way transmission of voice and data communication for specialized applications. In 1985, Hughes Network Systems developed the world's first two-way Ku-band VSAT system; by 1996, over 150,000 VSAT user terminals had been installed worldwide, with Hughes products comprising about two-thirds of the market. VSAT systems group voice and data transmissions into hybrid or homogenous channels for uplink to a geostationary satellite, typically operating in the Ku-band and then beamed directly to a VSAT terminal, hub or gateway or switched into public networks. Hybrid VSAT systems, which currently account for about 40 per cent of the Hughes VSAT market, are ideal for the low "tele-density" regions of western China. See Bhawani Shankar, "VSATs: Emerging from the Niche", *Telecommunications* (International Edition), February 1996, p. 36.

[317] See "Satellite Communications Network Opened for CAAC", *Xinhua New China News Agency*, 29 April 1996.

[318] *Ibid.* China is very pround of its affiliation with AsiaSat, particularly because it has enhanced China's regional leadership and prestige. In April 1990, China launched the first AsiaSat aboard the Long March 3 launch vehicle from Xichang, largely through the assistance of the Hughes Corporation (AsiaSat 1 was a Hughes HS-376 communication satellite). It provided domestic telecommunication services China, Thailand and Pakistan. AsiaSat 1 was a refurbished Westar VI retrieved from a useless orbit by a U.S. Space Shuttle mission. See David J. Whalen, "AsiaSat 2 - Asian Communications for the 21st Century", *Earth Space Review*, December 1995, pp. 13-19, and John D.R. Lawrence, "A Satellite for Asia", *The Future is Now!*, Asia Satellite Telecommunications Co. Ltd., 1989, pp. 55-59.

transportation demand"; he added that CAAC planned to build a second special satellite communication network during the ninth five-year plan.[319]

VHF Data Link System. In 1995, CAAC took the first major step of the mid-term phase of its CNS/ATM transition schedule by addressing China's immediate civil aviation communication needs.[320] On 11 September 1995, CAAC and ARINC signed a multiyear contract to establish a turn-key[321] air-to-ground digital data link system in China.[322] The agreement, allowing aircraft equipped with the data link to receive and transmit ATC and airline operational control (AOC) digital messages,[323] was a significant advance in China's effort to build the national civil aviation infrastructure required to support ICAO's global CNS/ATM standards. CAAC's command of an operational data link is a prerequisite for many CNS/ATM projects it wishes to conduct during the mid-term of the FANS transition schedule.

Phase I of the four-phase VHF data link[324] project, costing about $5 million and slated for completion in 1996, included the installation of a Network Management Data Processing System (NMDPS) and the outfitting of 25 remote ground stations (RGS)[325] in parts of eastern China.[326] This limited network will provide complete high-altitude coverage[327] along the high-density air traffic regions of eastern China. The network will support a wide variety of communication functions, including Pre-Departure Clearance (PDC) and Automatic Terminal Information Service (ATIS) tasks.[328]

Follow-on phases of the VHF data link program include the optional purchase and installation of an additional 95 RGS and the expansion of service nodes, including Controller-Pilot Data Link Communication (CPDLC).[329] Phase II of the project involves the installation of a second NMDPS, at either Xi'an or Guangzhou (Canton); this site will

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[319] *Ibid.*

[320] China's VHF air-to-ground data (A/G) link is the first project for transition to the new CNS/ATM system. During the construction of the network, CAAC reportedly is emphasizing the construction of its VHF A/G Data Communication Network (DCN) and its application systems. See Fan Weibing, Zhang Jun (Beijing University of Aeronautics and Astronautics, China), Tian Zhencai and Bi Xin'an (CAAC, Beijing), "Implementation of VHF Data Link for Civil Aviation in China", *Position, Location and Navigation Symposium*, Atlanta, GA, 22-26 April 1996, Proceedings, Institute of Electrical and Electronics Engineers, Inc., 1996, pp. 188-190. This paper presents the general description of Phase I: "the investigation of results of typical applications of ADS/ATC, a feasibility scheme for interconnecting with other VHF data networks, ARINC and SITA." *Ibid.*

[321] A turn-key system does not provide a specific service.

[322] See "ARINC/China in Datalink Deal", *Flight International*, 27 September 1995, "ARINC to Install Data Link Communications in China", *Aviation Daily*, 14 September 1995, p. 431, "ARINC to Provide Data Link System for China's Aviation Market", *World Airport Week*, 19 September 1995 and Brian Steinberg, "ARINC Inks Second Major Chinese Aviation Deal", *The Capital*, Annapolis, MD, p. A5. ARINC's major subcontractors for this project included IBM, Motorola and Alenia. The project, if all options are exercised, will require four years to complete.

[323] *Ibid.* China's VHF data link network resembles the Aircraft Communications Addressing and Reporting System (ACARS), which ARINC introduced to civil aviation in 1977. The installation of a network of remote ground stations (RGS) in tandem with a centralized control processing system, known as the Network Management Data Processing System (NMDPS), allows China to exploit the new generation of ACARS protocols.

[324] The "VHF data link" system is sometimes referred to as a "VDL" system.

[325] *Ibid.* Under the contract, ARINC will provide as many as 120 RGS throughout China over the next four years; network subcontractors include IBM, Motorola and Alenia. ARINC planned to install at least the first five RGS.

[326] The RGS sites range as far north as Jiamusi and as far south as Haikou. Xi'an lies outside the range of coverage to the west. See Bi Xin'an, Zhang Jun, Fan Weibing and Lu Boying, "VHF A/G Data Link in China", *International Aviation*, December 1995, pp. 35-36.

[327] Typically, CAAC's citation of "high altitude" refers to 7,000 meters. The RGS coverage radius at 7,000 meters is approximately 340 kilometers, sufficient to cover most parts of eastern China with the exception of a small area of airspace in the northeast bordering North Korea. *Ibid.*

[328] See ARINC Briefing (untitled), dated 3 October 1995.

[329] *Ibid.*

administer a series of approximately 50 RGS to support high-altitude, digital air-to-ground communication for international flights via Kunming, Europe and Mongolia.[330] Installation of the final set of 45-50 RGS will complete the domestic data link network. CAAC and ARINC envision that the entire communication network will "facilitate the expansion of air routes between North America and Asia while also laying the groundwork for similar route expansion between Asia and Europe."[331]

China's VHF data link program employs ARINC technology as well as underlying system architecture developed by China. The NMDPS consists of two back end processors (BEP), a journal processing system (JPS), a data link management subsystem (DLMS), a communication management subsystem (CMS) and a development/back-up system.[332] Additionally, a redundant hub/router links the entire NMDPS to CAAC's ground data network, an indigenously-enhanced, SITA-standard X.25 network;[333] the X.25 network is the key mechanism that links CAAC, regional ATC centers, the AOC's, the SATCOM GES's and the newly-established network of RGS ground stations.[334]

The ARINC agreement laid the foundation for CAAC to carry out the additional projects of its CNS/ATM transition schedule, as a reliable air-to-ground communication capability is an inherent requirement for all of China's CNS/ATM initiatives.

Among these initiatives was China's participation in one of the world's most significant FANS programs.[335] In 1997, CAAC reportedly utilized the NMDPS to test digital data link and ADS applications within the air space administered by the Beijing area control center. United Airlines, using a FANS-1 equipped Boeing 747-400, and Air China, using a Boeing 737, conducted these tests with the assistance of SITA, Raytheon and CAAC.[336]

Aeronautical Mobile Satellite Service. The third and final communication system priority of CAAC's CNS/ATM transition plan is aeronautical mobile satellite service (AMSS) technology. In 1996, CAAC intended to begin testing AMSS technology;[337] however, few details are available on the nature and scope of the initiative.[338] CAAC's preliminary plans in 1996 envisioned a three-part pilot program to

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[330] See Bi Xin'an, Zhang Jun, Fan Weibing and Lu Boying, "VHF A/G Data Link in China", *International Aviation*, December 1995, pp. 35-36.
[331] See "ARINC to Provide Data Link System for China's Aviation Market", *World Airport Week*, 19 September 1995.
[332] See Bi Xin'an, Zhang Jun, Fan Weibing and Lu Boying, "VHF A/G Data Link in China", *International Aviation*, December 1995, pp. 35-36.
[333] The X.25 is a common network interface protocol originally designed for applications using point-to-point, terrestrial networking facilities. See Terrence Skemer and Grahame Aitken, "Implementing Network Protocols Over Satellite: A Users Perspective", *The Future is Now!*, Telesat Canada, 1989, pp. 166-171.
[334] *Ibid.*
[335] See "Major Fans Programs", *Jane's Airport Review*, 1 January 1998, p. 32.
[336] See Chen Hengbao, "Air China Completed GPS/ACARS Demonstration Flight", *International Aviation*, January 1998, pp. 57-59.
[337] See CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the Joint Defense Conversion Commission (JDCC) (1996).
[338] Much of the baseline technology to support AMSS applications involves significant state investment in satellite technology. See Tong Kai and Guo Jianning, "Primary Analysis of the Development Approach to Chinese Satellite Mobile Communications", *AAIA Technical Library*, 1996, 19 p. This article describes China's need to develop satellite mobile communication (based on its national economic situation and level of satellite technology). It recommends that China participate in a "pan-national satellite mobile communication system" to resolve part of its international mobile communication requirement. It also recommends that China simultaneously develop a synchronous orbit, multiple beam satellite mobile communication system.

provide AMSS services regionally, laying the foundation to support international routes.[339]

One likely reason for the delay in AMSS testing is the close relationship between the menu of AMSS services, still being refined, and applied ADS technologies.[340] CAAC is also likely concerned about the air safety implications of mixing unproven multiple emerging technologies; the Aeronautical Mobile Satellite (Route) Service (AMS(R)S) pertains directly to the safety and regularity of flight. CAAC must ensure that this vital safety service is not impaired in any way as it shares the spectrum and satellites with a large number and great variety of other users of other services.[341] Finally, some Chinese researchers suggest that CAAC will lag at least five years behind ICAO's CNS/ATM FANS Committee implementation timeline because China's economic system and level of technology are insufficient.[342] As such, CAAC's general policy on the CNS/ATM system states that it will "implement AMS(R)S and ADS progressively"; there are no firm milestones for this transition.[343]

CAAC had much earlier in the decade developed a preliminary concept on implementing AMSS throughout China.[344] At that time, CAAC estimated that a national AMSS would have a cost-benefit advantage of 1:2.6, based principally on the large amount of air space in the remote western part of China, where its use would overcome the existing shortcomings of conventional ATM systems.[345] CAAC also envisioned that as a main element of AMSS, ADS would also provide clear ancillary economic and social benefits, citing the qualitative advantages of AMSS in supplanting China's insufficient network of ground-based, long-range HF radio facilities.[346] CAAC also noted the additional functions of AMSS, including the ability to conduct contingency communication (voice and data) and the capacity provide a wide range of civil air safety support services.[347]

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[339] The first, the northeast route, would cover scheduled civil air operations between Beijing, Dalian, Shenyang and Changchun. The second, the northwest route, would include Beijing, Taiyuan and Xi'an along the northwest to Europe via Lanzhou, Jiuquan, Urumqi and Aksu. Finally, the "trans-Eurasia route," would provide AMSS services in the area covering Chengdu, Kunming, Guiyang, Guilin and Nanning. See CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the Joint Defense Conversion Commission (JDCC) (1996).

[340] ICAO's Aeronautical Mobile Communications Panel (AMCP) drafted the AMSS SARP's, submitting the supporting documents to ICAO Air Navigation Commission (ANC) for ratification in May 1994. See Wassim Ferzali, Vassilis Zacharakis, Triveni Upadhyay, Dennis Weed and Gregory Burke, "Computer Simulation and Performance Assessment of the Packet-data Service of the Aeronautical Mobile Satellite Service (AMSS)" (conference paper), *Proceedings of the Fourth International Mobile Satellite Conference*, 1995, pp. 261-266.

[341] See Curtis Shively, "Automatic Dependent Surveillance Capacity of a Geostationary Satellite System in the U.S. Domestic Airspace" (conference paper), *Institute of Navigation*, National Technical Meeting, San Diego, CA, 27-29 January 1992.

[342] See Chen Guangren, "Preliminary Concept on AMSS Application in China", *International Aviation*, November 1992, pp. 46-47.

[343] See CAAC air space management briefing, dated 1995.

[344] See Chen Guangren, "Preliminary Concept on AMSS Application in China", *International Aviation*, November 1992, pp. 46-47.

[345] *Ibid.* ICAO recommends that its constituents assign the first generation of Aeronautical Mobile Satellite System (AMSS) to service in oceanic airspace and in areas with low air-traffic density. See Alain Delrieu and Claude Loisy, "Aeronautical Satellite Data Link System (SDLS) for High-density Air-Traffic Areas", *European Space Research and Technology Center*, Noordwijk, Netherlands, Proceedings of the Fourth International Mobile Satellite Conference, 1995, pp. 250-255.

[346] These advantages include high capacity, increases in quality and greater performances. *Ibid.*

[347] Such features include meteorological and en route automated information services (AIS), which the crew may query as non-voice communication. Many of these services rely on the controller-pilot data link communication feature of ADS. Successful AMSS flight trials were first carried out around the globe as early as the 1960's. However, a global system architecture among users, service providers and manufacturers is only recently beginning to be finalized. ICAO is prioritizing the different categories of AMSS communication, which includes ATC, aeronautical operational control (AOC), aeronautical administrative communication (AAC) and aeronautical passenger communication (APC). The Airlines Electronic Engineering Committee (AEEC) is developing the standards for the avionics required of large passenger planes. See Jack Rigley, "Aeronautical Mobile Satellite Service: An Overview" (conference paper), *Telesat Canada, The Future is Now!*, 1989, pp. 195-198.

Generally, CAAC's preliminary concept for AMSS implementation acknowledges the fundamental requirement for aircraft earth stations (AES), AMSS ground earth stations (GES) and satellite-based transmitters. CAAC envisions a phased, three-step approach to AMSS installation.[348] First, CAAC intends to install AMSS equipment in aircraft operating on international routes (Category A airliners); the Boeing 747-400 will be the first such aircraft to be provided with such communication capability, which will include a multi-channel voice-data AES. Second, CAAC will outfit China's domestic passengers airliners (Category B aircraft), also with multi-channel voice-data AMSS suites, focusing on the benefits of AMSS along the western routes. Finally, CAAC will outfit China's general aviation (GA) aircraft with less-advanced AMSS technology; these aircraft, subdivided by operation under Instrument Flights Rules (IFR) (Category C aircraft) or Visual Flight Rules (VFR) (Category D aircraft) will receive single-channel, voice-data AMSS suites and core function data communication AES, respectively.

CAAC intends to construct an eight-site AMSS GES network throughout China, relying on the existing structure of the Flight Information Regions (FIR) for GES services.[349] Beijing and Guangzhou will be the initial sites, with the Beijing GES serving as a network management station.[350] Following the installation of the entire AMSS network, the Beijing site will become the network coordinating station; Guangzhou will serve as the back-up facility.[351]

CAAC's preliminary concept for AMSS implementation envisions leasing International Maritime Satellite Corporation (Inmarsat) communication equipment and services to support the provision of AMSS services along international routes.[352] In 1992, CAAC enhanced its relationship with Inmarsat to improve its civil aviation mobile satellite communication.[353] The Beijing Marine Communication and Navigation Company, an Inmarsat member, sponsored a seminar for approximately 30 officials from Inmarsat, foreign airlines and satellite communication (SATCOM) service suppliers and 50 CAAC and China airline representatives. The parties agreed that China's aviation community would adopt a satellite-based, ground-to-air communication system. Air China announced at the seminar that it would install Inmarsat terminals for its Boeing 747 fleet to satisfy the communication needs of long-distance passengers and crews. The Beijing Inmarsat earth station, which opened in June 1991, reportedly is considering building an Inmarsat station that will provide communication between the satellites and national and international fixed telecommunication networks.

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[348] See Chen Guangren, "Preliminary Concept on AMSS Application in China", *International Aviation*, November 1992, pp. 46-47.
[349] *Ibid.*
[350] CAAC will complete the AMSS GES network by installing sites first in Shanghai and Xi'an and later in Chengdu, Shenyang, Urumqi and Wuhan. *Ibid.*
[351] *Ibid.*
[352] *Ibid.* The Inmarsat AMSS provides global air-to-ground and air-to-air communication services to civil aviation users. Communicating parties connect directly or by interconnecting networks to the Inmarsat AMSS to construct end-to-end communication circuits. The AES and the GES are the points of interconnection of the Inmarsat AMSS to users, as well as to interconnecting networks. See Jay R. Sengupta, "Inmarsat Aeronautical Mobile Satellite System: Internet Working Issues" (conference paper), *Proceedings of the 2nd International Mobile Satellite Conference*, 1990, pp. 15-32.
[353] See "Chinese Aviation Departments Improve Mobile SATCOMS", *Mobile Satellite News*, 29 June 1992.

CAAC plans to use an indigenously-developed, indigenously-launched AMSS transmitter to support domestic civil air operations, both in commercial air services and among general aviation aircraft; CAAC estimated that an indigenous system will save China approximately $14 million annually by the year 2010.[354] CAAC has encouraged China's relevant research and development organizations to begin to investigate the self-development of an AMSS transmitter capability, which CAAC recommends be operational by early in the next century.[355]

Navigation. To support the development of future air navigation, China intends to:[356]

1. gradually introduce a required navigation (RNAV) capability and begin to conform to the required navigation performance (RNP) concept.[357]
2. use GNSS to provide global navigation coverage for aircraft navigation and non-precision approaches.
3. adopt differential GNSS (DGNSS, or DGPS) techniques to replace instrument landing systems (ILS) to support precision approach and landing operations.
4. gradually withdraw conventional, terrestrial navaids from service.[358]
5. dissolve reliance on Omega and Loran navigation systems. Maintain and develop inertial navigation to support "combined forms" of navigation.

CAAC has stated that for the foreseeable future it will utilize existing GNSS/GPS navigation services.[359] However, CAAC also recommends China participate in a "pooled investment" to create a GNSS wide area augmentation system (WAAS). From a long-term perspective, China may join international plans to develop a civil GNSS constellation.

CAAC has planned two major navigation projects during the mid-term phase of the CNS/ATM transition: en route and terminal GNSS applications.[360]

GNSS – En Route. From 17-19 March 1996, China's Commission for Science, Technology and Industry for National Defense (COSTIND) joined CAAC in coordinating with an international team led by Rockwell's Communications System division (CSD) to conduct integrated CNS/ATM systems testing in Xi'an.[361] The tests, carried out with China's Research Institute of Navigation Technology[362] (RINT) (Xi'an)

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[354] See Chen Guangren, "Preliminary Concept on AMSS Application in China", *International Aviation*, November 1992, pp. 46-47.
[355] *Ibid.*
[356] See Zhou Qihuan, "The Evolutionary Change of the Air Traffic Environment", *International Aviation*, October 1995, p. 5.
[357] This proposal was a major consideration of the ATM joint task force, which recommended an emphasis on pilot projects, such as Beijing-Xi'an and Shanghai-Tianjin RNAV routes, to demonstrate the utility of new CNS/ATM technologies. The task force envisioned that the successful demonstration of these capabilities could easily lead to expanded use in other areas of China. See Paul Proctor, "Joint Effort Targets Chinese Air Safety", *Aviation Week & Space Technology*, 8 August 1994.
[358] These are primarily conventional ADF, NDB/VOR and DME sites.
[359] See Zhou Qihuan, "The Evolutionary Change of the Air Traffic Environment", *International Aviation*, October 1995, p. 5.
[360] See CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the Joint Defense Conversion Commission (JDCC) (1996).
[361] See Michael J. Ball, "ATM Demonstration in China", *Journal of ATC*, July-September 1996, pp. 26-28. Mr. Ball is Director of Air Traffic Management Systems for Rockwell International's Communication Systems Division.
[362] The Xi'an-based Research Institute of Navigation Technology (RINT) is China's leading GPS research organization. It is subordinate to the 20th Institute, Ministry of Electronics Industry (MEI).

and the CAAC Northwest Regional Administration, were the most comprehensive China has ever conducted.[363]

The three-day CNS/ATM demonstration involved two Cessna Citation II business jets from the China Flight General Aviation Company,[364] which were equipped with antennas and Rockwell avionics equipment pallets, a Northrop Grumman ADS workstation, a Collins/Daimler-Benz Aerospace (DASA) differential GPS (DGPS) ground station and an airport surface traffic surveillance system.[365] Rockwell equipped one of the Citations with a Collins AVSAT communication suite to provide constant tracking of the aircraft, through SITA, during its flight to Urumqi, a distance of over 1,700 kilometers (900 nautical miles). An HF data link reported the aircraft's position to an existing operational ground station.[366] The second Citation was fitted with a VHF data link and a GPS receiver to demonstrate Category I approaches to Xi'an's Xianyang Airport under digital GPS guidance.[367]

Although the trial did not include the participation of Air China or a domestic Boeing 737, as Rockwell had hoped, it nonetheless demonstrated to a large number of Chinese aviation engineers and managers the practical utility of CNS/ATM. Particularly significant was the revelation that CAAC could use GPS services and benefits with its existing communication systems; prior to the demonstration, some Chinese reportedly were uncertain whether CNS/ATM applied technology was technically feasible or remained as an ICAO topic for theoretical discussion and research.[368]

The Xi'an demonstrations illustrated the benefits of satellite-based ATM (SBATM) in four phases of flight: en route, terminal area, approach and airport surface surveillance. It also led to four main accomplishments:[369]

1. integration of all required communication assets (SATCOM, HF and VHF) from multiple nodes (en route, terminal area and approach, ground surveillance and secondary surveillance radar);
2. creation of a seamless, single workstation display for all phases of flight: the national en route control (all of China), for a terminal area (Xianyang Control

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[363] See "Chinese at ATC Test", *Aviation Week & Space Technology*, 25 March 1996, p. 30. According to this article, over 100 senior Chinese aviation and ministry officials visited Xi'an to view the trials, which the U.S.-led team conducted despite a political standoff between the U.S. and China over ongoing presidential elections in Taiwan. Among the non-Chinese attendees were representatives of ICAO, the International Air Transportation Association (IATA) and the Federal Aviation Administration (FAA). See "Rockwell Satellite-based Air Traffic Management Demonstration in Xi'an, China Shows the Benefits of a CNS/ATM Solution", *Business Wire*, 10 April 1996.

[364] For many years, the China Flight General Aviation Company (in Chinese, "zhongfei tongyong hangkong gongsi") (CFGAC) has provided civil aircraft platform support to the China Flight Test Establishment (CFTE). Rockwell-Collins has had a similarly long relationship with both organizations, part of an association with China since the mid-1970's that now extends to supplying avionics equipment to China's regional, domestic, and international airlines. See "Pressurized Y-8 Undergoes Tests", *Flight International*, 23 October 1991. Rockwell-Collins also provides the PLAAF with electronic support systems, including electronic flight information systems (EFIS) for the Nanchang K-8 tandem trainer. See "K-8 Ready for Service but Lacks PLA Budget", *Aviation Week & Space Technology*, 12 February 1996, p. 27.

[365] See Paul Lewis, "The Long March", *Flight International*, 6 November 1996.

[366] *Ibid.* China's continued interest in HF stems from the large number of HF-equipped airliners that now comprise the civil air fleet.

[367] *Ibid.*

[368] See Bruce D. Nordwall, "Demo Bolsters China's Credibility in ATM", *Aviation Week & Space Technology*, 15 April 1996, p. 36.

[369] See "Rockwell Satellite-based Air Traffic Management Demonstration in Xi'an, China Shows the Benefits of a CNS/ATM Solution", *Business Wire*, 10 April 1996.

Area), for an airport (Xianyang Approach), and for a ground surveillance environment (Xianyang Ground Control);

3. successful category I approaches using differential GPS (DGPS); and
4. displays of airport authority vehicle position based on DGPS during

The successful trials were particularly significant to China's conceptualization of possible CNS/ATM applications among future routes in its western region, particularly among potential routes to and from Europe. By successfully integrating GPS functions with a data link-based communication subsystem, CAAC and the Chinese technicians and leaders who attended the demonstration attained a much clearer perspective on the practical benefits of emerging CNS/ATM technologies.[370] As a result of these advances, CAAC decided to conduct further tests using the Boeing 737, with the intent to eventually trial dynamic routing techniques and establish a prototype ADS route.[371]

GNSS – Terminal Area. In mid-1993, China began a four-year research effort on the domestic civil aviation applications of GNSS technology.[372] Under the auspices of the State Council, CAAC and the Civil Aviation Institute of China (CAIC),[373] Air China conducted GPS/ACARS evaluation tests as part of scheduled flights between February 1996 and August 1997. The original evaluation plan included tests of GNSS applications for en route navigation, non-precision approaches and CAT I precision approach and landing operations. However, China canceled the CAT I tests, reportedly because of the requirement to structurally modify the aircraft and prepare a special-use airfield to test differential GPS (DGPS) technologies.[374]

China selected its most numerous commercial jet, the Boeing 737-300, as the test platform, retrofitting it with two sets of GPS satellite navigation receivers to establish bi-directional data communication between the aircraft and ground stations. The retrofit also included a VHF receiver, a data communication controller and two 4-microcontrol unit (MCU) flight management computers (FMC).

The GPS demonstration flights tested the minimal functional standards of signal coverage, availability, reliability and accuracy on a variety of scheduled flights in different regions of China, including Beijing-Guangzhou (Canton), Kunming-Yangguang, Qingdao-Wuhan and Beijing-Xi'an. The resultant analysis indicated that the GPS signal was in accord with the demands of all phases of domestic civil air flight

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[370] See "Rockwell To Lead GPS Demonstration In China", *Aviation Daily*, 8 February 1996, p. 214.

[371] See Paul Lewis, "The Long March", *Flight International*, 6 November 1996.

[372] See Chen Hengbao (Air China), "Air China Completed GPS/ACARS Demonstration Flight", *International Aviation*, January 1998, pp. 57-59.

[373] Located in Tianjin, CAIC serves as the training institute for about half China's mid-level airline managers and about 70 percent of its civil air traffic controllers. It is also China's primary training center for airline mechanics, engineers and technicians. China's government-owned factories have developed a separate training system for mechanics and engineers; education is provided by six or seven schools, primarily the Northwestern Polytechnical University (NPU/Xi'an) and at aviation universities in Beijing and Nanjing, under the auspices of the Aviation Industries of China (AVIC). CAIC's role as an ATC training center is crucial for China's future ATM development. In 1995, CAIC and CAAC announced a joint administration of the Nanjing University of Aeronautics and Astronautics (NUAA). See Rusty Shughart, "China's Civil Aviation Industry: Modernization, Technology Transfer and National Defense", *U.S. Air Force Institute for National Strategic Studies*, 1 October 1996, 211 pages.

[374] See Chen Hengbao (Air China), "Air China Completed GPS/ACARS Demonstration Flight", *International Aviation*, January 1998, pp. 57-59.

operations.[375] The Air China analysis suggested that China investigate DGPS and Wide Area Augmentation System (WAAS) applications as part of future ATM demonstration initiatives.[376]

CAAC's CNS/ATM transition plan also calls for China to conduct trials of GPS support technology in the terminal phase of flight. In the near future CAAC hopes to collaborate with Japan on civil air GPS capabilities. Japan is developing the most significant project to support the regional institution of CNS/ATM system concepts in the Asia-Pacific region. Its Multifunctional Transport Satellite (MTSAT), which the Japan Civil Aviation Bureau developed in tandem with the FAA, will provide ATC services for civil aviation over a ten-year mission life, augmenting GPS signals for civil air navigation.[377] A major feature of the MTSAT project is its planned interoperability with other satellite-based wide-area augmentation systems (WAAS),[378] fulfilling the ICAO requirement for seamless, global interoperability.[379] Japan plans to launch the MTSAT via a Japanese H-2 rocket in 1999 as a successor to the Geostationary Meteorological Satellite-5 (GMS-5).[380] In addition to providing ATC support services, the MTSAT will also maintain satellite imaging, image data distribution, and meteorological data collection from data collection platforms for meteorological services for a five-year mission life.[381] In addition, CAAC is conducting applied research on future indigenously-developed CNS/ATM systems implementation in China. Such research includes the development of differential GPS (DGPS) systems to enhance the services of satellite-based global navigation systems.[382]

Surveillance. To support the development of future air surveillance, China will:[383]

1. develop A and C mode SSR or S mode SSR for surveillance of terminal areas and of high-density continental air space.
2. use automatic dependent surveillance (ADS) in other air space until it is finally used universally in other areas, overlapping with SSR.
3. gradually withdraw primary surveillance radar (PSR) from service.

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[375] See Chen Hengbao (Air China), "Air China Completed GPS/ACARS Demonstration Flight", *International Aviation*, January 1998, pp. 57-59.
[376] *Ibid.*
[377] See Shinichiro Sukegawa, "Air Traffic Implementation in the Asia-Pacific Region", *Aerospace and Electronic Systems Magazine*, March 1997, pp. 33-37. The MTSAT will regional augmentation services to aviation, maritime, and land users.
[378] In addition to the MTSAT, there are two other major wide-area augmentation systems (WAAS) under development around the world today. The FAA is developing a system for North America; a consortium of European organizations is developing the European Geostationary Navigation Overlay System (EGNOS) to cover western Europe.
[379] See James Fernow, Daniel O'Laughlin, Daniel, T. T. Hsiao, and James Reagan, "Interoperability between Satellite-based Augmentation Systems" (conference paper), *Institute of Navigation*, Albuquerque, NM, 2 July 1997, pp. 473-482.
[380] See Seiichiro Kigawa, " Requirements of MTSAT/Imager", Meteorological Satellite Center Technical Note Number 30, *Meteorological Satellite Center*, Tokyo Japan, No. 30, 1995 pp. 33-39.
[381] *Ibid.*
[382] CAAC has tested DGPS methods to raise positioning precision and carry out long-range differential tests from Xi'an to Luoyang and Jinxi. The test results have led to the recommendation to create a domestic DGPS network. See Lu Guohua and Liu Yanli, "Long Range Differential GPS and the Concepts of Chinese Plans to Establish Broad Area Networks", *AIAA Technical Library*, 1996, 26 p.
[383] See Zhou Qihuan, "The Evolutionary Change of the Air Traffic Environment", *International Aviation*, October 1995, p. 5.

CAAC has only one major surveillance project as part of its civil aviation CNS/ATM transition schedule: Automatic Dependent Surveillance (ADS).[384]

Automatic Dependent Surveillance. From March to October 1996, CAAC conducted China's most significant Automatic Dependent Surveillance (ADS) test, a gradual, three-phase program conducted with the assistance of CAAC's North China Regional ATC Administration, Air China, SITA, Raytheon, Boeing, United Airlines and Cathay Pacific Airlines.[385] The trial incorporated the services of a wide range of CNS/ATM emerging technologies, including an experimental data link, a United Boeing 747-400 equipped with a FANS-1 package and an Air China Boeing 737-300 outfitted with a GPS and ADS-compatible avionics.[386]

In phase one of the trial, air traffic controllers at Beijing's Shoudu (Capital) International Airport used VHF and satellite communication to connect with the two airliners, using SITA's X.25 uplink to a satellite ground station.[387] CAAC utilized Raytheon's Autotrac workstations to track both domestic and international civil air flights, including the domestic air space portion of a United flight from Chicago to Hong Kong.[388] In June, phase two added radar data to the ADS display, integrating the system with a Raytheon solid-state L-band primary surveillance radar and a Cossor monopulse SSR in use at Beijing.[389] It also allowed CAAC to assess its ability to simultaneously track two aircraft with dissimilar communication protocols, periodic and temporary.[390] In October, phase three added a controller-pilot data link communication (CPDLC) system to the trial, providing the Beijing controllers the capability to send digital messages to modify the altitude and heading of the aircraft.[391] The trial also included the successful surveillance of the approach and departure of a FANS-1-equipped Cathay Pacific Airways 747-400 operating on a flight from Hong Kong to Tokyo.[392]

CAAC's successful ADS trials were a significant step in China's understanding of the practical benefits and challenges of CNS/ATM implementation. Particularly significant to CAAC was the evidence that it could rely on ADS technology to support dynamic routing among scheduled domestic flights as well as to ease congestion along high-density international routes.[393] These general perspectives were

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[384] See CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the Joint Defense Conversion Commission (JDCC) (1996).

[385] See Lu Xiaoping and Liu Jinhua, "ADS Flight Test in Beijing Capital Airport", *International Aviation*, November 1997, pp. 27-28.

[386] The Boeing 737-300, which China acquired in November 1995, was designated PQ-373. See Zhou Qihuan, "China's First B737 Upgraded for GPS/RNP/ACARS Capabilities", *Civil Aviation Economics and Technology*, March 1996, pp. 22-26.

[387] The controllers maintained track observations on both aircraft within the distance and range of conventional VHF ground stations. *Ibid.*

[388] See Paul Lewis, "The Long March", *Flight International*, 6 November 1996.

[389] Ibid. This reportedly was the first time this system had been extended to a multi-sensor ADS/radar environment.

[390] See Lu Xiaoping and Liu Jinhua, "ADS Flight Test in Beijing Capital Airport", *International Aviation*, November 1997, pp. 27-28. There was no bidirectional data link communication during this phase.

[391] *Ibid.*

[392] The Boeing 747-400 is an extended-range version of the four-engine airliner that the U.S. and several Asian countries have invested in to bypass Japan on international routes between Asia and North America. See Bruce D. Nordwall, "Asia/Pacific Leads FANS-1 Progress", *Aviation Week & Space Technology*, 12 August 1996, pp. 48-49.

[393] The regional director of the International Air Transport Association (IATA) has noted that China is interested in creating a CNS/ATM-supported Bangkok connection, via Urumqi; this route would avoid the congested corridor over Calcutta, while saving 10-15 minutes of flight time. He added that CAAC must install suitable ADS workstations, in either Chengdu or Urumqi to support CNS/ATM advances, provide qualified controllers and persuade the PLAAF to provide additional air space for such operations. See Paul Lewis, "The Long March", *Flight International*, 6 November 1996.

part of CAAC's derived conclusions from its ADS trials.[394] Specifically, these findings proved that the surveillance and communication applications of ADS technology in China:

1. are feasible, both from the perspective of planning and technology.
2. can provide coverage in areas beyond the range of conventional radar, doing so with relatively simple equipment and lower baseline investment costs.
3. can incorporate many applications beyond positioning information. A collaborative investment in ADS support systems can result on multiple benefits at reduced cost.
4. can, through the CPDLC, reduce the degree of labor-intensive ATC involvement in civil air operations while increasing the reliability of communication and command authority in an environment not limited by the bounds of voice communication.
5. could be enhanced beyond the 64-second automatic data link reporting minima of the trial to meet the requirements of utilization along high-density air routes and approach control areas.[395]
6. will be less-expensive when employed within the range of conventional VHF coverage. The need to rely on satellite services for ADS messaging to aircraft beyond the range of VHF will increase the investment costs for the airlines and aircraft owners.
7. will support direct flight routing – unconstrained by conventional waypoints – among scheduled flight operations, of huge economic benefit to the airlines.[396]

CAAC's ADS trials led China to participate in the implementation of a seasonal CNS/ATM air route along the Beijing-Harbin-Russia border, a route which is among the first in the world to use emerging CNS/ATM applied technologies.[397]

Air Traffic Management. To support the development of future ATM enhancements during the CNS/ATM transition phase, China will:[398]

1. maintain or enhance existing air safety levels.
2. increase system capacity to meet requirements.
3. make full use and capacity of resources to meet air traffic requirements.
4. play a regulatory role in dynamic air tracking. This tracking, when

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[394] See Lu Xiaoping and Liu Jinhua, "ADS Flight Test in Beijing Capital Airport", *International Aviation*, November 1997, pp. 27-28.
[395] Although ADS is designed to support low-density air operations, such as in the air space of oceanic or remote regions, it can also support high-density environments as a back-up to secondary surveillance radar (SSR), particularly in areas where the SSR network does not provide continuous, unbroken surveillance. See Paul Lewis, "The Long March", *Flight International*, 6 November 1996.
[396] A Rockwell study from March 1996 estimated CAAC would spend over $1 billion if it opted to upgrade it conventional ATC system, a system which would "still fall short of meeting even the most pessimistic forecasts in air-traffic growth over the next 20 years." In comparison, the creation of a CNS/ATM system would double air traffic capacity and lower life-cycle costs, generating $2.7 billion in additional revenue. The study added that a CNS/ATM system would "provide Chinese airlines with a cumulative saving of more than $33 billion in fuel, more than offsetting the projected $500 million cost of upgrading and maintaining CNS/ATM avionics by 2015." Finally, it estimated that China could earn revenue from CNS/ATM overflight user fees that would almost double that of a ground-based system, "more than sufficient to finance the new satellite-based system." See Paul Lewis, "The Long March", *Flight International*, 6 November 1996.
[397] See Bruce D. Nordwall, "Asia/Pacific Leads FANS-1 Progress", *Aviation Week & Space Technology*, 12 August 1996, pp. 48-49.
[398] See Zhou Qihuan, "The Evolutionary Change of the Air Traffic Environment", *International Aviation*, October 1995, p. 5.

necessary, will involve controller intervention to maintain safe separation distances. CAAC envisions that ATM enhancement will provide users with improved information, concerning weather conditions, the dynamic air traffic situation and equipment reliability. Dynamic air tracking will yield improved navigation and landing functions as well as supporting advanced approach and departure procedures.

5. help users engage in decision-making processes, to include air-to-ground computer dialogue on relevant flight consultations.

6. reduce on-station delays and waiting. CAAC envisions that ATM enhancements will support in-flight adjustments based on real flight tracking to more effectively use air space and airports.

7. strengthen the strategic planning contributions of ATS, allowing its use to reduce and resolve future flight conflicts.

Although CAAC does not envision significant changes to its Flight Information Region (FIR) structure, it hopes to eventually reduce the number of high-altitude ACC's from 26 to ten[399] and the number of low and medium altitude ACC's from 37 to 25.[400] There is no fixed timetable for this reform; however, the current emphasis of the "three-center project" appears to be an initial technical step toward eliminating system redundancy. Such a significant development will likely occur over the span of several five-year plans.

Long-Term Transition Objectives. Beyond the mid-term of CAAC's CNS/ATM transition plan, China hopes to command a flexible, highly efficient air traffic environment. Although CAAC has not published specific milestones for the long-term phase (2001-2015) of the transition, it generally intends to establish all CNS technical support systems to foster a national ATM upgrade. These systems include SATCOM, VHF data link (VDL), and AMSS (communication); en route and terminal area GNSS (navigation); and ADS (surveillance). Collectively, the integration of these systems will form the major component of China's effort to support globally integrated civil aviation in the future. China's envisions that the ATM environment of the long-term phase of the transition will differ greatly from the system that exists today:[401]

1. The support of applied CNS/ATM technologies will form reliable, beyond visual range (BVR) and globally-unbroken coverage in air communication, navigation and surveillance. CAAC envisions VHF and AMSS will ensure total air-to-ground communication; the combination of satellite and inertial navigation systems will greatly raise navigation precision; and SSR and ADS will strengthen dynamic tracking capability.

2. The exchange of air-to-ground information will extend to the terrestrial network through the ATN, improving the information exchange capabilities of the ATC

[399] The ten high-altitude area control centers are slated for construction at Beijing, Shanghai, Shenyang, Guanzhou, Wuhan, Chengdu, Kunming, Xi'an, Sanya and Urumqi). See CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the Joint Defense Conversion Commission (JDCC) (1996).

[400] The 25 low and medium-altitude area control centers are slated for construction at Hailar, Harbin, Shenyang, Dalian, Beijing, Taiyuan, Huhhot, Ji'nan, Zhengzhou, Shanghai, Hefei, Nanchang, Xiamen, Wuhan, Changsha, Nanning, Guangzhou, Sanya, Kunming, Guiyang, Chengdu, Xi'an, Lanzhou, Urumqi and Aksu. See CAAC air space management briefing provided to the Air Force and DoD Liaison on Civil Aviation Issues as part of the Joint Defense Conversion Commission (JDCC) (1996).

[401] See Zhou Qihuan, "The Evolutionary Change of the Air Traffic Environment", *International Aviation*, October 1995, p. 5.

units. All data of the flight plan, en route progress, contingency consultations, hand-offs and weather services will be exchanged by network, forming the basis of air traffic automation.

3. The radar network, the ADS data network and the ADS satellite data link will ensure that all aircraft receive abundant surveillance. It will also form the explicit foundation for civil air control and flow management.

4. High-precision 3- and 4-dimensional navigation will permit the rank ordering of flights according to RNP along certain routes and areas, reducing flight separation.

5. The route structure will not be tied to the existing grid of ground navaids. The adoption of RNAV will allow parallel and sequential routes capable of meeting ideal routing selected by air operators.

6. The realization of greater real time tactical control system, namely a pseudo-radar control system stemming from a combination of radar control and ADS, will strengthen air traffic controllers' ability to support contingencies, raising ATC efficiency and safety.

7. ATM automation will lead to a relatively reduced amount of air space management, thus maximizing the utilization rate of limited air space resources.

8. The long-term and short-term enhancements of aircraft flow management will increase route and airport utilization rates while reducing aircraft on-station time and delays.

9. The automation of ATM services will lead to a highly efficient, advanced, globally integrated civil air transportation system.

Recommendations on Future Development. As a nationally integrated systems project of very high scientific and technical content, China's future ATM system will require a significant investment in personnel and resources of the supporting realms of communication, navigation, weather and computer processing. Some Chinese ATM analysts have noted that China's economic and scientific situation adds to this complexity, making it very difficult for CAAC to conduct ATM applied system testing during the transition period to FANS.[402] These analysts have suggested that China must consider and resolve at least the following eight issues to position itself to smoothly accept and adopt the tenets of the air navigation system of the future:[403]

1. establish relevant support organizations to conduct required scientific and technical work.[404]

2. institute tangible research and development projects.

3. enhance the management of unified infrastructure to support primary system projects.

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[402] See Qin Zhi and Zhou Qihuan, "Thinking about the Development of CNS/ATM in China", *International Aviation*, June 1998, pp. 46-47 and Zhang Lihua (ed.), "Strive in Concord to Implement CNS/ATM"; *Civil Aviation Economics and Technology*, September 1995, pp. 16-17.

[403] *Ibid.*

[404] CAAC ATMB Director Chen Xuhua has expressed an interest in developing a technical support center for ATM planning and design work (this proposal reportedly has been submitted to the CAAC senior leadership). Although CAAC largely oversees the activities of several research institutes, these organizations are academic in nature, lacking system implementation planning. Based on an interview with Mr. C.C. Hsin, Director of International Programs, *Mitre Corporation*, 23 December 1997.

4. advance the research work related to air-to-ground satellite communication and HF/VHF data links.

5. resolve the application problems of the WGS-84 coordinate system in China.[405]

6. resolve the display problems of information synthesis and integration.

7. expedite the enhancement of FANS applications in the northwest and southwest regions of China.

8. strengthen the air safety and security guarantees.

These analysts have also noted that China does not necessarily need to follow the path of the developed nations in procuring and fielding the most advanced technology in building its modern ATM system.[406] They perceive many of the emerging ATM technologies as a rush by manufacturers to capture the newly developing market.[407] While acknowledging that concepts such as "free flight" are valid CNS/ATM objectives for the future, these analysts have cautioned China on adopting a policy of "leap-frogging" domestic technology gaps to institute the most advanced CNS/ATM systems.[408] The intervening steps of infrastructural development and specialized training are prerequisites for the successful construction of China's future civil air traffic environment. Comprehensive planning; phased reform; a gradual pace of transition; avionics and airport development; and procedural regularization are factors equal in significance to that of technology.[409] Together, these elements form a coherent approach to the complex task of constructing China's future ATM environment as a cohesive system that ensures safety, improves service and strives for flight responsibility.

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[405] The World Geodetic System (WGS) is the datum utilized by GPS reference stations; Russia's Global Navigation Satellite System (GLONASS) uses the PZ-90 datum. See P. N. Misra and E.M. Gasposchkin, "Integrated Use of GPS and GLONASS - Transformation Between WGS-84 and PZ-90", *Proceedings of the 9th International Technical Meeting of the Satellite Division of the Institute of Navigation*, Kansas City, 17-20 September 1996, pp. 307-314. Through applied research conducted by the Northwestern Polytechnical University, China encountered appreciable errors transferring the Gauss-Kruger coordinates of a known differential GPS reference station to the WGS-84 system. The refinement of this process is key to achieving the degree of signal accuracy required to utilize GPS navigation services in the terminal approach and landing phase of flight. See Li Yong, Yuan Jianping and An Ning (Northwestern Polytechnical University), "On Analyzing System Transformation Errors Related to a Differential GPS Reference Station", Journal of the Northwestern Polytechnical University, August 1997, pp. 466-470.

[406] See Qin Zhi and Zhou Qihuan, "Thinking about the Development of CNS/ATM in China", *International Aviation*, June 1998, pp. 46-47.

[407] In the absence of a national master plan for civil aviation, CAAC continues to emphasize product and system procurement, such as the "three-center project," to the expense of important conceptualization work. Based on an interview with Mr. C.C. Hsin, Director of International Programs, *Mitre Corporation*, 23 December 1997.

[408] See Qin Zhi and Zhou Qihuan, "Thinking about the Development of CNS/ATM in China", *International Aviation*, June 1998, pp. 46-47.

[409] *Ibid.*

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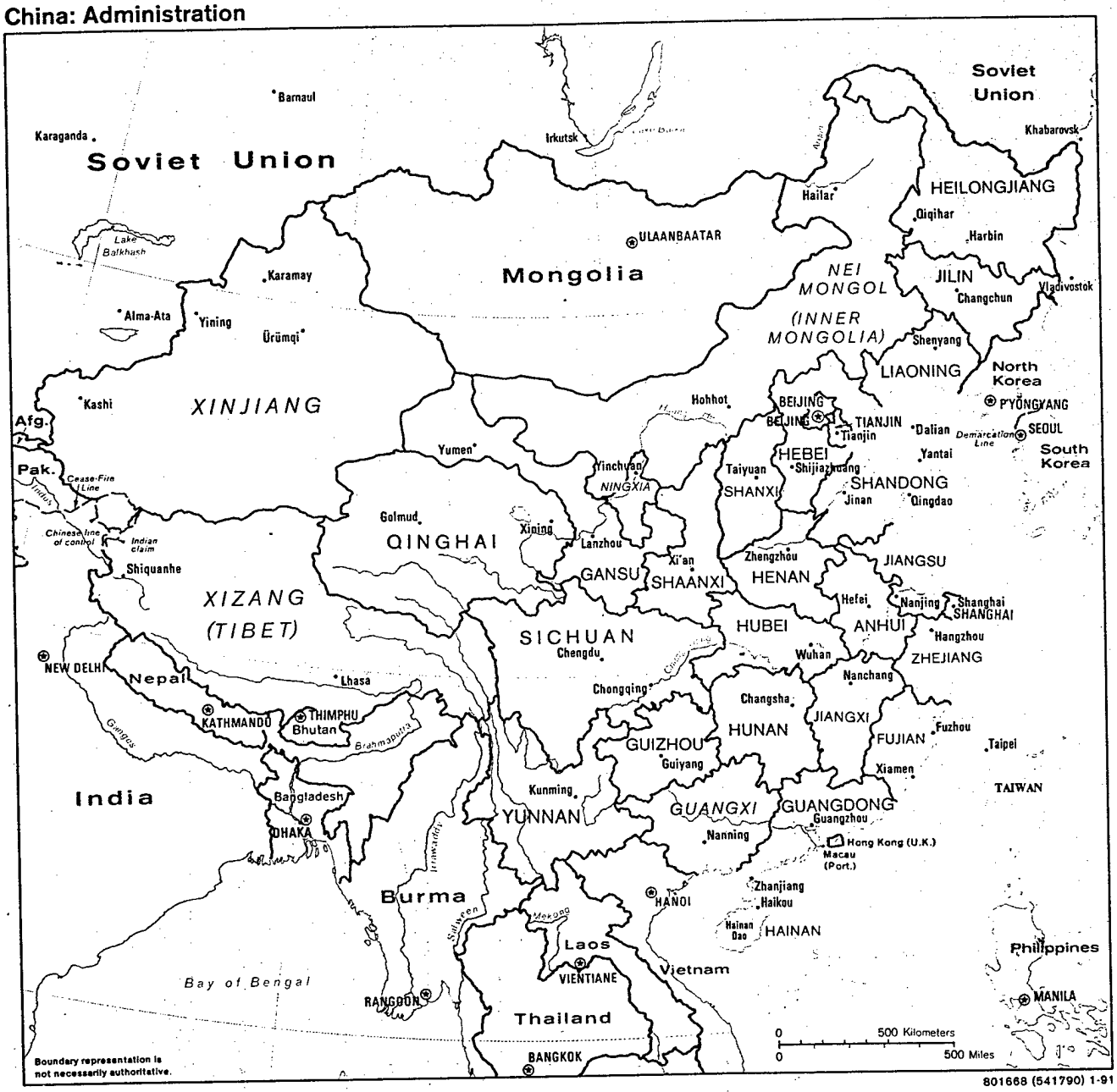

Province-Level Names

Characters	Pinyin	Pronunciation
安徽	Anhui	ahn-way
北京	Beijing	bay-jing
福建	Fujian	foo-jee_en
甘肃	Gansu	gahn-soo
广东	Guangdong	g_wong-doong
广西	Guangxi	g_wong-she
贵州	Guizhou	g_way-joe
海南	Hainan	hi-nan
河北	Hebei	huh-bay
黑龙江	Heilongjiang	hay-loong-jee_ong
河南	Henan	huh-nan
湖北	Hubei	hoo-bay
湖南	Hunan	hoo-nan
江苏	Jiangsu	jee_ong-su
江西	Jiangxi	jee_ong-she
吉林	Jilin	jee-lynn

Characters	Pinyin	Pronunciation
辽宁	Liaoning	lee_ow-ning
内蒙古	Nei Mongol	nay-mung-goo
宁夏	Ningxia	ning-she_ah
青海	Qinghai	ching-hi
陕西	Shaanxi	shun-she
山东	Shandong	shahn-doong
上海	Shanghai	shong-hi
山西	Shanxi	shahn-she
四川	Sichuan	ssu-ch_wan
天津	Tianjin	te_en-jin
新疆	Xinjiang	shin-jee_ong
西藏	Xizang	she-dzong
云南	Yunnan	yu_oon-nan
浙江	Zhejiang	juh-jee_ong
台湾	Taiwan	tie-wan

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Major Rusty Shughart
(703) 604-0475