MANUFACTURING PROCESSES

Machine tool and jet engine technologies are priority acquisition targets for the PRC. This chapter presents two case studies relating to the PRC's priority efforts to obtain such technology — its 1994 purchase of machine tools from McDonnell Douglas, and its efforts in the late 1980s and early 1990s to obtain jet engine technology from Allied Signal's Garrett Engine Division.

McDonnell Douglas Machine Tools

In 1993, China National Aero-Technology Import and Export Corporation (CATIC) agreed to purchase a number of excess machine tools and other equipment from McDonnell Douglas, including 19 machine tools that required individual validated licenses to be exported. CATIC told McDonnell Douglas it was purchasing the machine tools to produce parts for the Trunkliner Program, a 1992 agreement between McDonnell Douglas and CATIC to build 40 MD-82 and MD-90 series commercial aircraft in the PRC.

During the interagency licensing process for the machine tools, the Defense Technology Security Administration sought assessments from the Central Intelligence Agency and from the Defense Intelligence Agency, because of concerns that the PRC could use the McDonnell Douglas five-axis machine tools for unauthorized purposes, particularly to develop quieter submarines. Since the PRC wishes to enhance its power projection capabilities and is making efforts to strengthen its naval forces, the five-axis machine tools could easily be diverted for projects that would achieve that goal.

Initially, CATIC told McDonnell Douglas it planned to sell the machine tools to four factories in the PRC that were involved in the Trunkliner commercial aircraft program. When those efforts reportedly failed, CATIC told McDonnell Douglas it planned to use the machine tools at a machining center to be built in Beijing to produce Trunkliner parts for the four factories.

In May 1994, McDonnell Douglas applied to the Commerce Department for licenses to export the 19 machine tools to the PRC. Even after it became apparent that only 20 of the 40 Trunkliner aircraft would be built in the PRC, the U.S. Government continued to accept McDonnell Douglas's assertion that the machine tools were still required to support the Trunkliner production requirements. Accordingly, Commerce approved the license applications in September 1994 with a number of conditions designed to limit the risk of diversion or misuse.

In April 1995, the U.S. Government learned from McDonnell Douglas that six of the licensed machine tools had been diverted to a factory in Nanchang known to manufacture military aircraft and cruise missile components, as well as commercial products. However, Commerce's Office of Export Enforcement (OEE) did not initiate an investigation of the diversion for six months.

The Commerce Department declined an Office of Export Enforcement Los Angeles Field Office request for a Temporary Denial Order against CATIC. The case remains under investigation by OEE and the U.S. Customs Service. With the approval of the U.S. Government, the machine tools have since been consolidated at a factory in Shanghai.

Garrett Engines

The PRC has obtained U.S. jet engine technology through diversions of engines from commercial end uses, by direct purchase, and through joint ventures. Although the United States has generally sought to restrict the most militarily sensitive jet engine technologies and equipment, the PRC has reportedly acquired such technologies and equipment through surreptitious means.

Prior to 1991, Garrett jet engines had been exported to the PRC under individual validated licenses that included certain conditions to protect U.S. national security. These conditions were intended to impede any attempt by the PRC to advance its capability to develop jet engines for military aircraft and cruise missiles.

The 1991 decision by the Commerce Department to decontrol Garrett jet engines ensured that they could be exported to the PRC without an individual validated license or U.S. Government review. In 1992, the Defense Department learned of negotiations between Allied Signal's Garrett Engine Division and PRC officials for a co-production deal that prompted an interagency review of Commerce's earlier decision. The interagency review raised a number of questions regarding the methodology Commerce had followed in its decision to decontrol the Garrett jet engines.

The PRC continues its efforts to acquire U.S. jet engine production technology. The PRC may have also benefited from the direct exploitation of specially designed U.S. cruise missile engines. According to published reports, the PRC examined a U.S. Tomahawk cruise missile that had been fired at a target in Afghanistan in 1998, but crashed en route in Pakistan.

MANUFACTURING PROCESSES

PRC EFFORTS TO ACQUIRE MACHINE TOOL AND JET ENGINE TECHNOLOGIES

The People's Republic of China's long-term goal is to become a leading power in East Asia and, eventually, one of the world's great powers. To achieve these aims, the PRC will probably enhance its military capabilities to ensure that it will prevail in regional wars and deter any global strategic threat to its security.[1]

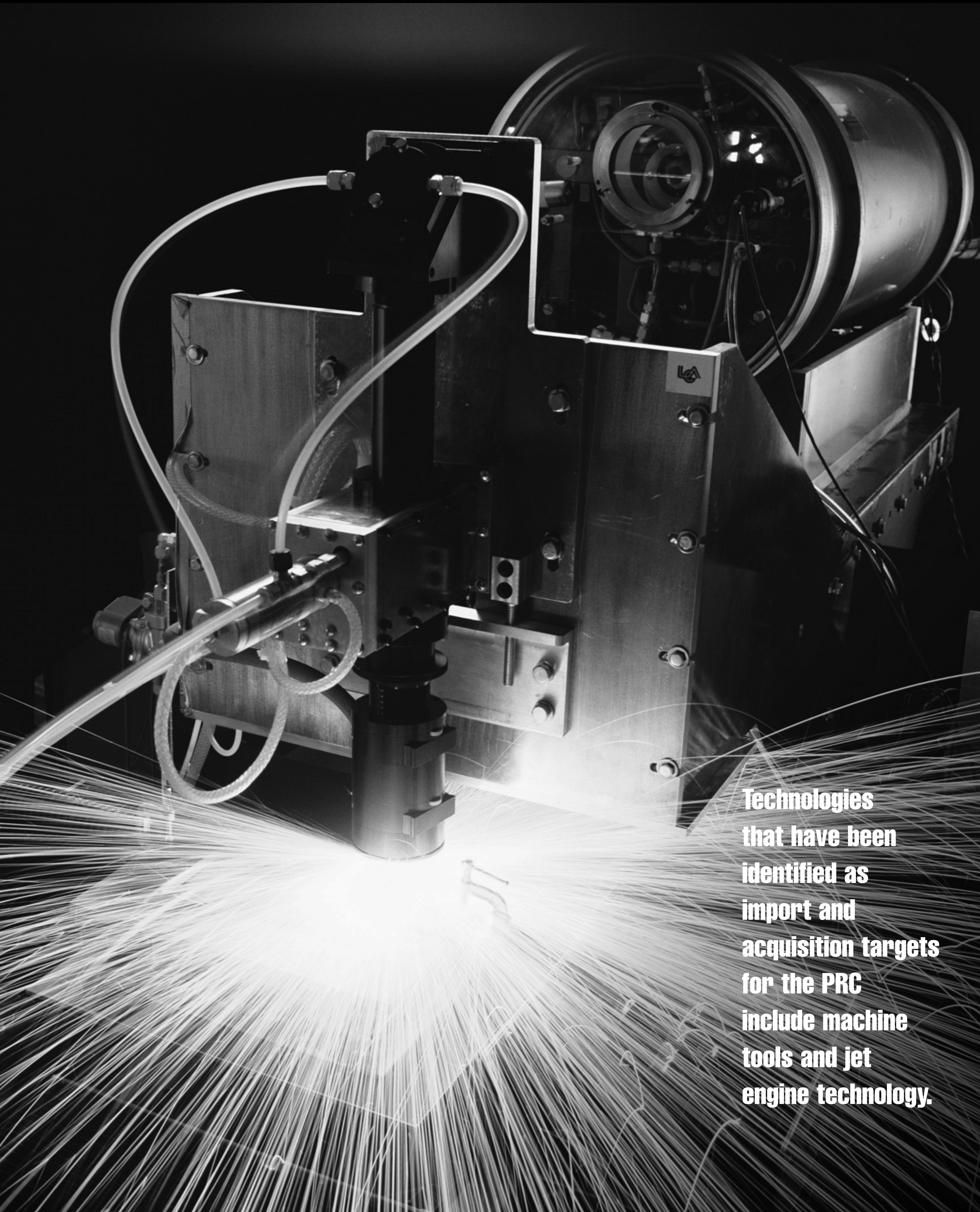
From the PRC's perspective, the 1991 Gulf War was a watershed event in which U.S. weapons and tactics proved decisive. The war provided a window on future warfare as well as a benchmark for the PRC's armed forces.[2]

After the Gulf War, senior PRC military leaders began speaking of the need to fight future, limited wars "under high-tech conditions."[3] Senior PRC political leaders support the military's new agenda.[4]

In a 1996 speech, Li Peng, second-ranking member of the Politburo, then-Prime Minister, and currently Chairman of the National People's Congress, said:

> *We should attach great importance to strengthening the army through technology, enhance research in defense-related science, . . . give priority to developing arms needed for defense under high-tech conditions, and lay stress on developing new types of weapons.*[5]

Senior PRC leaders recognize that enormous efforts must be made to "catch up" militarily with the West.[6] According to the Defense Intelligence Agency, the PRC's



Technologies that have been identified as import and acquisition targets for the PRC include machine tools and jet engine technology.

ability to achieve this goal depends in part on its "industrial capacity to produce advanced weapons without foreign technical assistance."[7]

Two technologies that have been identified as priority acquisition targets for the PRC are machine tools for civil and military requirements, and jet engine technology.[8] This chapter presents two case studies relating to the PRC's efforts to obtain such technologies — its 1994 purchase of machine tools from McDonnell Douglas, and its efforts in the late 1980s and early 1990s to obtain jet engine technology from Allied Signal's Garrett Engine Division.

These case studies illustrate the methods the PRC has used to acquire militarily-sensitive technologies through its skillful interaction with U.S. Government and commercial entities.

However, the case studies do not assess the degree to which the PRC has enhanced its aerospace and military industrial capabilities through the acquisition of U.S. technologies and equipment.

A third technology priority for the PRC — composite materials — is discussed in the Technical Afterword to this chapter.

PRC Targeting of Advanced Machine Tools

The PRC is committed to the acquisition of Western machine tool technology, and the advanced computer controls that provide the foundation for an advanced aerospace industry.

Although the PRC acquires machine tools from foreign sources in connection with commercial ventures, it also seeks foreign-made machine tools on a case-by-case basis to support its military armament programs.

Moreover, the proliferation of joint ventures and other commercial endeavors that involve the transfer or sale of machine tools to the PRC makes it more difficult for foreign governments and private industry to distinguish between civilian and military end-uses of the equipment.

The China National Aero-Technology Import-Export Corporation's (CATIC) purchase of used machine tools from McDonnell Douglas, now part of Boeing, is one illustration of the complexities and uncertainties faced by private industry and the U.S. Government in these endeavors.

Traditional machine tools cut, bend, and shape metals and non-metal materials to manufacture the components and structures of other machines. Machine tools form the foundation of modern industrial economies, and are widely used in the aerospace and defense industries.

The capability of machine tools is typically indicated by the number of linear or rotational motions — of either the tool or the workpiece — that can be continuously controlled during the machining process, and by the machining accuracy that can be achieved. The latter is measured in microns, that is, millionths of a meter.

Advanced machine tools can provide five axes of motion — typically horizontal, lateral, and vertical movement, and rotation on two perpendicular axes. Less widely used or required are six- and seven-axis machines, which are sometimes used for special applications.

Machine tools used in aircraft and defense manufacturing today are generally numerically controlled (NC). More advanced equipment is computer numerically controlled (CNC). CNC machine tools are essential to batch production of components for modern weapon systems, and can reduce machining times for complex parts by up to 90 percent compared to conventional machine tools.

In addition, these modern machines require operators with less skill and experience and, when combined with computer-aided design software, can reduce the manufacturing cycle of a product, from concept to production, from months to days.

Machine tools are essential to commercial industry, and high precision, multiple-axis machine tools broaden the range of design solutions for weapon components and structural assemblies. Parts and structures can be designed with advantages in weight and cost relative to what could be achieved with less advanced machine tools. For military and aerospace applications, the level of manufacturing technology possessed by a country directly affects the level of military hardware that can be produced, and the cost and reliability of the hardware.[9]

The military/civilian dual-use production capability of various types of machine tools is indicated in the following table.

Some Military and Civilian Uses of Machine Tools

Machine Tool Type	Conventional Military Applications	Nuclear Applications	Civilian Applications
Precision lathes	Inertial guidance system parts; high performance fuel-pump parts; tank transmissions	Parts for uranium enrichment centrifuges and laser isotope separation	Automotive transmissions; VCRs; CDs; computer components
Diamond turning lathes	Reflecting mirrors for laser gyros; harpoon missile advanced optical system	Hemishells	Molds for contact lenses; prisms for optical equipment; computer hard drives
Large center-drive lathes	Gun barrels for 120 and 150 mm cannons (external cuts)	(No critical application)	Turbine shafts; large motor shafts; propeller shafts
Mills	Stabilization and aiming systems for M1A1 tanks; Airframe and missile parts	Enrichment components	Instrument brackets; large computer frames; airframe parts
Large five-axis mills	Aircraft parts; propellers for Navy ships and submarines	(No critical application)	Aircraft parts; propellers for commercial ships
Small five-axis mills	Jet engine impellers	Enrichment components	Compressor pumps for fluids
Grinders	Radar systems for aircraft; inertial guidance system parts; helicopter main shaft bearings; gas turbine blades; high performance fuel pumps	Enrichment components, tooling and fixturing	High speed motor shafts and bearings; automotive injector valves; dies, molds, pumps

Source: Export Administration Regulations, Part 742.

Export Controls on Machine Tools

The PRC's access to foreign multi-axis machine tools and controllers has increased rapidly with liberalized international export controls.[10]

During the Cold War, the Coordinating Committee for Multilateral Export Controls (COCOM) established multilateral controls on exports to the Warsaw Pact allies and the PRC of machine tools that restricted linear positioning accuracy below 10 microns.[11] However, the consensus for relatively strict export controls dissolved after the Soviet Union's collapse.

The post-Cold War control regime is embodied in the 1996 Wassenaar Arrangement, and the 1978 Nuclear Suppliers Group Agreement (NSG) governing the export of machine tools that can be used for nuclear weapons development. This current regime has a different focus, as indicated in the following table.

Comparison of COCOM, Wassenaar, and the Nuclear Suppliers Group

Feature	COCOM	Wassenaar	NSG
Purpose	Control high-technology transfers to Communist countries	Prevent destabilizing accumulations of arms and dual-use goods. Focus on threats from transfers of armaments and dual-use goods to destinations where the risks are judged greatest	Restrict exports or reexports of items with nuclear applications
Extent of Export Controls	Communist Bloc	Countries of Concern	Non Members
Export Approval	Multilateral Consent	National Discretion	National Discretion

The Wassenaar and Nuclear Suppliers Group Agreement regimes have adopted similar control parameters for machine tools. Generally speaking, lathes and milling machines must be licensed for export if their accuracy exceeds six microns. Grinding machines are controlled at four microns. The Wassenaar Arrangement controls all machine tools capable of simultaneous, five-axis motion, regardless of machining accuracy. The Nuclear Suppliers Group Agreement exempts certain machines from this restriction.[12]

The PRC is not a proscribed destination for machine tools and other commodities under the Wassenaar Arrangement. This means that Wassenaar regime members treat exports to the PRC according to their individual national discretion. On the other hand, exports to the PRC of Nuclear Suppliers Group Agreement-covered items require individual validated licenses.[13]

Export Administration Regulations

The Wassenaar and Nuclear Suppliers Group Agreement parameters for machine tool controls have been incorporated in the U.S. Commerce Department's Commodity Control List of dual-use items (the list appears in the Export Administration Regulations).[14] Machine tools are listed under Category 2 (Material Processing), Group B (Inspection and Production Equipment).[15]

The Commodity Control List further classifies machine tools — as it does other dual-use items — by an Export Control Classification Number that reflects the item's category, group, types of associated controls, whether the item is controlled for unilateral or multilateral concerns, and a sequencing number to differentiate among items on the Commodity Control List.[16]

The PRC's Machine Tool Capabilities and Foreign Acquisitions

Observers of the PRC's machine tool capabilities do not believe that the PRC can indigenously produce high precision, five-axis machines that approach the quality of Western products.

The U.S. General Accounting Office estimates that the PRC has the capability "to manufacture less sophisticated machine tools, but cannot currently mass produce four- and five-axis machine tools that meet Western standards."[17]

According to a 1996 Defense Department assessment, however, the PRC's indigenous machine tool production capability is increasing markedly.[18]

The PRC has long sought to compensate for its deficiencies in machine tool technology by importing foreign systems. This approach has been facilitated by COCOM's dissolution and the resulting international relaxation of controls on machine tool exports.

Since the end of COCOM in March 1994, PRC military industries have acquired advanced machine tools that would be useful for the production of rocket and missile guidance components, and several five-axis machines for fighter aircraft and parts production. Five-axis machines were controlled under COCOM and are purportedly controlled by Wassenaar.[19] U.S. industry sources note that:

> *China has proved able to buy [machine tools] from a variety of foreign makers in Japan and Europe. Between 1993 and 1996, fifteen large, 5-axis machine tools were purchased by Chinese end users — all fifteen were made by Western European manufacturers.*
>
> *Furthermore, Shenyang Aircraft purchased twelve 5-axis machine tools [in 1997]. These machine tools came from Italian, German and French factories.*[20]

In addition, the PRC may be enhancing its ability to produce advanced machine tools through license production arrangements with Western manufacturers.

Other countries developing nuclear weapons and missiles have also apparently benefited from the PRC's ability to acquire advanced machine tools on the world market. As one recent Defense Department assessment noted, the PRC's "recent aerospace industry buildup and its history of weapons trade with nations under Western embargoes makes this increase in key defense capacity of great concern." [21]

The Clinton administration has determined that specific examples of this activity cannot be publicly disclosed.

CASE STUDY: McDonnell Douglas Machine Tools

Findings of the U.S. General Accounting Office

The Select Committee has determined that the U.S. Government is generally unaware of the extent to which the PRC has acquired machine tools for commercial applications and then diverted them to military end uses.

The McDonnell Douglas case illustrates that the PRC will attempt diversions when it suits its interests.

At the request of Congress, the U.S. General Accounting Office in March 1996 initiated a review of the facts and circumstances pertaining to the 1994 sale of

McDonnell Douglas machine tools to CATIC. The GAO issued its report on November 19, 1996.

The report can be summarized as follows:

- **In 1992, McDonnell Douglas and China National Aero-Technology Import and Export Corporation (CATIC) agreed to co-produce 20 MD-82 and 20 MD-90 commercial aircraft** in the PRC. Known as the Trunkliner Program, the aircraft were to serve the PRC's domestic "trunk" routes. In late 1994, a contract revision reduced the number of aircraft to be built in the PRC to 20, and added the purchase of 20 U.S.-built aircraft.

- **CATIC is the principal purchasing arm of the PRC's military** as well as many commercial aviation entities. Four PRC factories, under the direction of Aviation Industries Corporation of China (AVIC) and CATIC, were to be involved in the Trunkliner Program.

- **In late 1993, CATIC agreed to purchase machine tools and other equipment from a McDonnell Douglas plant** in Columbus, Ohio that was closing. The plant had produced parts for the C-17 transport, the B-1 bomber, and the Peacekeeper missile. CATIC also purchased four additional machine tools from McDonnell Douglas that were located at Monitor Aerospace Corporation in Amityville, New York, a McDonnell Douglas subcontractor.

- **The machine tools were purchased by CATIC for use at the CATIC Machining Center in Beijing — a PRC-owned facility that had yet to be built** — and were to be wholly dedicated to the production of Trunkliner aircraft and related work. McDonnell Douglas informed the U.S. Government that CATIC would begin construction of the machining center in October 1994, with production to commence in December 1995.

- **In May 1994, McDonnell Douglas submitted license applications for exporting the machine tools to the PRC and asked that the Commerce Department approve the applications quickly** so that it could export the machine tools to the PRC, where they could be stored at CATIC's expense until the machining facility was completed. Following a lengthy interagency review, the Commerce Department approved the license applications on September 14, 1994, with numerous conditions designed to mitigate the risk of diversion.
- **During the review period, concerns were raised about the possible diversion of the equipment to support PRC military production**, the reliability of the end user, and the capabilities of the equipment being exported. The Departments of Commerce, State, Energy, and Defense, and the Arms Control and Disarmament Agency, agreed on the final decision to approve these applications.
- **Six of the machine tools were subsequently diverted to Nanchang Aircraft Company, a PRC facility engaged in military and civilian production** over 800 miles south of Beijing. This diversion was contrary to key conditions in the licenses, which required the equipment to be used for the Trunkliner program and to be stored in one location until the CATIC Machining Center was built.
- **Six weeks after the reported diversion**, the Commerce Department suspended licenses for the four machine tools at Monitor Aerospace in New York that had not yet been shipped to the PRC. Commerce subsequently denied McDonnell Douglas's request to allow the diverted machine tools to remain in the unauthorized location for use in civilian production. The Commerce Department approved the transfer of the machine tools to Shanghai Aviation Industrial Corporation, a facility responsible for final assembly of Trunkliner aircraft. The diverted equipment was relocated to that facility before it could be misused.

- **The Commerce Department did not formally investigate the export control violations until six months after they were first reported**. The U.S. Customs Service and the Commerce Department's Office of Export Enforcement are now conducting a criminal investigation under the direction of the Department of Justice.[22]

The U.S. Government's Actions in Approving the Export Licenses

On December 23, 1993, the China National Aero-Technology Import and Export Corporation (CATIC) reached an agreement to purchase machine tools from McDonnell Douglas. CATIC officials signed the purchase agreement with McDonnell Douglas on February 15, 1994.

A May 27, 1994 e-mail message to Assistant Secretary of Commerce for Export Administration Sue Eckert from Deputy Assistant Secretary for Export Administration Iain Baird noted:

> *We received 23 applications covering all of the material involved in this project two days ago. [McDonnell Douglas] plans on shipping to CATIC.*
>
> *We have a long history with CATIC, which has been the consignee on numerous occasions — approved and denied based on licensing policies in effect at the time. CATIC was also the entity that attempted to buy the Machine Tool plant in the Northwest that was "denied" under the CFIUS process.*
>
> . . . .
>
> *Because of the sensitivity of this case, I think we should get it to the ACEP [Advisory Committee for Export Policy] ASAP. We are going to suggest to the other agencies that we forgo the 60-90 [day] review process and, instead, bring together all the relevant experts in a special [Operating Committee] meeting in 2-3 weeks to make a recommendation.*

> *If it is not agreed to approve the transaction at that point*
> *(and it won't be),*
> *we'll get the issue before the next ACEP.*
>
> *Stay tuned.*[23]

Subsequently, according to a June 8, 1994 memorandum to Deputy Assistant Secretary of Defense for Counterproliferation Policy Dr. Mitchel Wallerstein from Acting Director of the Defense Technology Security Administration Peter Sullivan:

> *An interagency meeting was held 7 June 1994. Defense, State and Commerce were in attendance; Energy and CIA were invited but did not attend.*
>
> *McDonnell Douglas representatives outlined their proposal. They would like closure on their license applications by 5 July 1994.*
>
> *The possibility of meeting that request seems remote. First, initial staffing within DoD was accomplished 7 June 1994, when we received the required documentation from Commerce. Second, all parties agree that the prospects for escalation within the [U.S. Government] seem high, due to the scope of the proposed program, and the precedence [sic] it may establish. We will keep you informed of additional developments.*[24]

Within the Defense Department, the McDonnell Douglas license applications were a cause of concern and internal debate. Specifically, the uniformed military services (Joint Staff) initially recommended denial.

The Joint Staff based its recommendation of denial upon an analysis indicating a high probability that this technology would be diverted for PLA end use.[25] Moreover, the Joint Staff noted that, "Even with DoD recommending approval with conditions, this would be a less-than-prudent export to the PRC. This is particularly true in light of Chinese involvement in the world arms market."

The Staff of the U.S. Commander in Chief, U.S. Pacific Command, agreed, noting in an August 1, 1994 memorandum to the Joint Staff that it "concurs with the Joint Staff position to deny…"

The Licensing Officer at the Defense Technology Security Administration who was initially assigned responsibility for the McDonnell Douglas license applications also recommended denial. The Licensing Officer reiterated concerns as to CATIC's role in both civilian and military production, and stated that "[n]o quantitative data has been supplied by the exporter, which establishes a clear need for this equipment in China [the PRC]."

Intelligence Community Assessments

Because of concerns that the McDonnell Douglas machine tools would give the PRC manufacturing production capabilities in excess of what was required for the Trunkliner Program, the Department of Defense asked for information that would assist it in determining whether these machine tools could be diverted to production of PLA military aircraft.

A July 27, 1994 Defense Intelligence Agency response to a request from the Defense Technology Security Administration provided an assessment.[26] It warned that, while similar machine tools were available from foreign sources, there was a significant risk of diversion. There was also the additional risk that the PRC could reverse-engineer the machine tools, and then use them in other commercial or military production. This would be consistent with the PRC's practice of reverse-engineering other Western technology for military purposes.

On August 9, 1994, the Defense Intelligence Agency provided a supplemental report explaining the results of its thorough assessment of the applicability of the McDonnell Douglas machine tools to three known PLA fighter aircraft programs, each of which incorporated stealth technologies. The report concluded:

> *The establishment of an advanced machine tool facility presents a unique opportunity for Chinese military aerospace facilities to access advanced equipment which otherwise might be denied.*

In 1994 McDonnell Douglas machine tools suitable for aircraft and missile production were purchased from this Columbus, Ohio facility by the China National Aero-Technology Import and Export Corporation (CATIC). The plant had produced parts for the United States' B-1 bomber, C-17 transport, and Peacekeeper missile.

Similarly, placing these machine tools in one facility would reduce the financial outlay needed to acquire duplicate advanced machine tools for multiple military aircraft programs.

DIA . . . maintain[s] that the production capacity resulting from the McDonnell Douglas sale is above and beyond the requirement necessary for exclusive production of 20 MD-82 and 20 MD-90 McDonnell Douglas [aircraft], which is the stated end use in the export license application.

In fact, recent press reporting indicates China [the PRC] has dropped plans to build 20 MD-82s and will limit future production to just 20 MD-90 aircraft.[27]

The Defense Technology Security Administration had received information from informants in September 1993 — prior to CATIC's agreement to purchase the machine tools, and a full year before the license was granted — that CATIC personnel had visited McDonnell Douglas's Columbus, Ohio plant and videotaped the machine tools in use, a potentially illegal technology transfer.

The Defense Technology Security Administration reported the information to the U.S. Customs Service, and its agents later paid a visit to the Columbus, Ohio plant. However, following the visit, the U.S. Customs Service determined that no further investigative action was warranted.

During the interagency licensing process for the machine tools, the Defense Technology Security Administration also sought assessments from the Central Intelligence Agency and from the Defense Intelligence Agency, because of concerns that the PRC could use the McDonnell Douglas five-axis machine tools for unauthorized purposes, particularly to develop quieter submarines. Since the PRC wishes to enhance its power projection capabilities and is making efforts to strengthen its naval forces, the five-axis machine tools could easily be diverted for projects that would achieve that goal.

The Defense Technology Security Administration received additional information from informants indicating that CATIC had provided the Shenyang Aircraft Factory, an unauthorized location, with a list of the Columbus, Ohio equipment that had been purchased from McDonnell Douglas.[28] Circles around some of the items on the list, according to the translation of a note from Shenyang that accompanied the list, indicated that the Shenyang Aircraft Factory was interested in obtaining those items from CATIC.

The Shenyang list was reportedly obtained from the discarded trash at a CATIC subsidiary in California.

This list was viewed as proof that CATIC intended to divert the machine tools to unauthorized locations. These concerns were reported to the U.S. Customs Service in the summer of 1994.

McDonnell Douglas and the China National Aero-Technology Import and Export Corporation (CATIC) agreed in 1992 to co-produce 20 MD-82 *(above)* and 20 MD-90 *(below)* aircraft in the PRC. The PRC purchased machine tools from McDonnell Douglas, ostensibly for use in manufacturing these aircraft. But the PRC diverted them to a facility known to manufacture military aircraft and cruise missile components as well as civilian products.

Changes to the Trunkliner Program

When McDonnell Douglas applied for export licenses on May 26, 1994, the applications noted that the machine tools would be used by the Beijing CATIC Machining Center primarily for the Trunkliner program. According to those license applications, McDonnell Douglas had a contract with CATIC to co-produce 20 MD-82 and 20 MD-90 aircraft.[29]

In June 1994, McDonnell Douglas representatives provided a series of briefings to officials from the Commerce, State, and Defense Departments regarding the nature of the Trunkliner program and McDonnell Douglas's other activities in the PRC.[30] In July 1994, however, *Flight International* magazine announced that the Trunkliner Program had been significantly changed.[31]

Instead of co-producing 20 MD-82 and 20 MD-90 aircraft in the PRC, only 20 MD-90 aircraft would be built there. Although the PRC would still acquire 20 additional aircraft, those would now be built at McDonnell Douglas's Long Beach, California plant — albeit with many parts that were to be fabricated in the PRC.

Prompted by the press reports, the Defense Department sought additional information from McDonnell Douglas in late July and early August 1994 regarding how the machine tools would be employed if the number of aircraft to be co-produced in the PRC was to be reduced.[32]

In letters to the Defense Technology Security Administration dated August 8 and August 12, 1994, McDonnell Douglas provided further clarification regarding the number and complexity of the parts that were to be manufactured in the PRC.

Commerce Department Licensing Officer Christiansen recalls that Commerce was not concerned that the number of aircraft to be co-produced in the PRC might be reduced, since parts for the aircraft would continue to be fabricated in the PRC.[33]

The Defense Technology Security Administration and the Defense Department, on the other hand, were concerned since they thought the machine tools might represent significant excess manufacturing capacity that the PRC might be tempted to divert to other, unauthorized uses.

The actual agreement that reduced the number of aircraft to be assembled in the PRC was signed on November 4, 1994.[34]

Discussions in the Advisory Committee for Export Policy

The McDonnell Douglas export license applications were discussed at the June 24, 1994 meeting of the Advisory Committee for Export Policy (ACEP).

According to the minutes of that meeting, no decision was reached. The Defense Department representative at the meeting advised against approving the licenses that day, because internal Defense Department review was continuing. The Defense Department believed the applications could be approved if reasonable safeguards were put into place to prevent the machine tools from being used for unauthorized purposes.[35]

Among the other agencies in attendance, the State Department agreed with the Defense Department that further review was required. The Department of Energy deferred to the Defense Department on whether licenses should be approved.[36]

The license applications for the McDonnell Douglas machine tools were again discussed at a meeting of the Advisory Committee for Export Policy on July 28, 1994. Again, the matter was deferred until the next Advisory Committee meeting. The minutes reflect that "a final decision on this transaction would have to be remanded until the next meeting of the ACEP, or as soon as possible before that date, if all the agencies complete their reviews earlier."

According to the ACEP minutes, the respective positions of each agency on the applications were as follows:[37]

- **[The Department of Defense] said that, if it had to vote at that time, it would recommend denial of the licenses** because of concerns that the machine tools would be diverted. Moreover, there were concerns that the McDonnell Douglas machine tools would give the PRC excess production capacity, thus allowing other machine tools in its inventory to be diverted from civilian to military production.

- **[The Department of] Energy indicated that, without further review, "it would have to defer to Defense in denying this transaction and the underlying applications."**
- **[The Department of] State recommended approval,** provided that appropriate safeguards and conditions could be formulated to minimize the risk of diversion.
- **[The] Arms Control and Disarmament Agency agreed with DOD [the Defense Department]'s position, noting that it would recommend denial** of the license applications should it have to vote at that time.
- **[The Department of] Commerce recommended approval** with conditions to minimize the risk of diversion to unauthorized uses.

The License Is Issued

The Advisory Committee member agencies later agreed to issue the export licenses with 14 conditions.[38]

Those conditions required, among other things, that:

- **The machine tools were to be stored in one location pending completion of the Beijing CATIC Machining Center**
- **McDonnell Douglas was to provide quarterly reports to the Department of Commerce and the Defense Technology Security Administration should the Beijing CATIC Machining Center not be completed when the machine tools arrived**[39]

As a final part of the licensing process, a Department of State cable was sent to the U.S. Embassy/Beijing on August 29, 1994 requesting that a senior CATIC official provide a written end use assurance that the machine tools would only be used for specified purposes.[40]

In a September 13, 1994 response, the U.S. Embassy/Beijing reported that it had obtained the assurance from CATIC Deputy Director Sun Deqing. However, the cable also noted that Deqing had indicated to the embassy officials that:

> *CATIC plans to establish several specialized factories under their new CATIC Machinery Company, and that [the CATIC Machining Center] would be one of those plants. [The CATIC Machining Center] will be established either near Beijing . . . or in Shijianzhuang at the Hongxing Aircraft Company . . .*[41]

Six of the machine tools from the McDonnell Douglas plant in Columbus, some of which are pictured in a cargo container, were diverted from a not-yet-built CATIC machining center in Beijing to the Nanchang Aircraft Company, a PRC facility engaged in the production of both military and civilian aircraft 800 miles south of China's capital city.

McDonnell Douglas's Plans

McDonnell Douglas's Limited Role at the Machining Center

Although McDonnell Douglas was planning to place up to four of its employees at the Beijing CATIC Machining Center, this was not to occur until late 1995 at the earliest.

Moreover, the Machining Center was not to be a joint venture between CATIC and McDonnell Douglas. Rather, it was to be a CATIC facility that supported CATIC's responsibilities to the Trunkliner Program.

Trunkliner Program

Media reports indicated in July 1994 that McDonnell Douglas and the PRC were engaged in negotiations over the number of Trunkliner aircraft to be assembled in the PRC.[42]

Notes from a June 7, 1994 briefing that McDonnell Douglas provided to U.S. Government officials regarding its license applications indicate that McDonnell Douglas's representatives made references to the fact that the company was negotiating with the PRC over changing the mix of aircraft to be built in the PRC.[43] CATIC was to remain responsible for the fabrication of large numbers of parts both for the aircraft that would be assembled in the PRC, and for the aircraft that were to be built in the United States under an "offset" agreement.

When queried by DOD officials regarding the continued PRC need for the machine tools in light of possible changes to the Trunkliner program, McDonnell Douglas responded in an August 8, 1994 letter to Defense Technology Security Administration Acting Director Sullivan. The letter provided further explanation regarding CATIC's proposed use of the machine tools. A subsequent August 12, 1994 McDonnell Douglas letter to the Defense Technology Security Administration's Colonel Henry Wurster noted:

> *. . . The PRC factories that are participating in the Trunk Aircraft Program . . .do not have the capability individually, nor collectively, to accomplish the work share the PRC has agreed to (75 percent of the airframe) . . . If the licenses are*

denied, the PRC would purchase these types of machines somewhere else . . .

Commerce Department Delays Investigating Machine Tool Diversion for Six Months

The Commerce Department's Actions in April 1995

As part of the licensing conditions for the machine tools, the machines tools were to be stored in one location pending completion of the Beijing machining center, and McDonnell Douglas was required to ". . . notify the [U.S. Government] of the location of the machine tools and update the [U.S. Government] with any changes of location prior to plant completion."

In April 4, 1995 letters to the Commerce Department's Office of Export Enforcement, Washington Field Office, and to the Technical Information Support Division/Office of Exporter Services, McDonnell Douglas reported that the machine tools were located at four different places:

- **Nine of the machine tools were located at two sites in the port city of Tianjin, a two hour drive from Beijing**
- **Four other machine tools had yet to be exported and were located at Monitor Aerospace Corporation in Amityville, New York**
- **Six machine tools were reported to be at the Nanchang Aircraft Company** [44]

According to the letters, a McDonnell Douglas employee had physically observed the machine tools in Tianjin, and confirmed that they remained in their original crates. He had not personally viewed the machine tools at the Nanchang Aircraft Company. However, the McDonnell Douglas letters reported that:

. . . CATIC did provide the attached letter to substantiate the list of equipment stored there. CATIC stated that the equipment has *<u>not</u>* *been unpacked and remains in the original crates.*
[Emphasis in original]

The April 4 McDonnell Douglas letters did not trigger any kind of investigative response.

On April 20, 1995, an interagency meeting was held in which two McDonnell Douglas officials discussed the status and locations of the machine tools. The McDonnell Douglas officials reported that there had been changes in the number of aircraft that would be built jointly with the PRC, and changes in the location of the machine tools.

Since the machine tools were not stored in one authorized location, this violated the licensing conditions. McDonnell Douglas representatives responded by stating that the machine tools had inadvertently been moved to more than one location contrary to what had been specified in the export licenses, but that the building for the machine tools had not been completed and the tools had to be stored somewhere in the interim.

Six months later the Office of Export Enforcement received additional information from Commerce Department Licensing Officer Christiansen that, in conjunction with a formal request from the Defense Technology Security Administration, finally triggered the opening of a formal investigation into the diversion.

The Commerce Department's Actions in October 1995

An October 5, 1995 e-mail from Christiansen to a number of Commerce Department officials, including Office of Export Enforcement Acting Director Mark Menefee, reported that one of the six machine tools in storage at the Nanchang Aircraft Company had been uncrated, and was in the final stages of assembly.

In clear violation of the export license, the machine tool — a hydraulic stretch press — had been installed in a building that apparently had been built specifically to accommodate that piece of equipment.

In his e-mail message, Christiansen stated:

> *For OEE [the Office of Export Enforcement], please investigate to determine who was responsible for both the diversion of the equipment originally and second who is responsible for the*

decision to install the equipment at Nanchang.

The formal request from the Defense Technology Security Administration for an investigation consisted of an October 4, 1995 letter from its Director of Technology Security Operations.[45] The Defense Technology Security Administration informed the Acting Director of the Office of Export Enforcement, Mark Menefee, that:

> *During last week's ACEP [Advisory Committee for Export Policy] meeting a package of materials were handed out concerning the violation of McDonnell Douglas's export license to the Chinese.*
>
> *The facts of the case are that CATIC has intentionally misused the export licenses to put controlled technology at a facility not authorized to receive [it].*
>
> *This facility as confirmed by the Chinese is involved in the manufacture of both missiles and attack aircraft. I will be forwarding a copy of those materials to you separately.*
>
> *We believe that this is a very serious matter and that the Office of Export Enforcement should conduct a serious investigation into this matter . . .*

The Office of Export Enforcement determined that an active investigation was warranted, and opened a case file in early November 1995. The case was forwarded to the Office of Export Enforcement's Los Angeles Field Office for investigation because McDonnell Douglas Aircraft in Long Beach, California — the exporter of record for the machine tools — was located in the Los Angeles Field Office's area of responsibility.

Allegation that the Commerce Department Discouraged the Los Angeles Field Office's Investigation

On June 7, 1998, the CBS program "*60 Minutes*" suggested that the Commerce Department or other U.S. Government entities were not necessarily interested in a complete and thorough investigation of the machine tool diversion. Among other things, the program included a brief appearance by Marc Reardon, a former Los

Angeles Field Office special agent, who had initially been assigned to investigate the case. According to the official CBS transcript of the program:

> ***[CBS journalist Steve] KROFT: (Voiceover)*** *And there's still some debate over just how hard the Commerce Department tried to find out who the bad guys really were. It took them six months to open an investigation. And Marc Reardon, the Commerce Department case agent assigned to investigate, says higher ups in Washington didn't seem anxious to get to the bottom of things.*
>
> *Did you feel like you were getting support from the department?*
>
> ***Mr. Marc REARDON:*** *No. Not at all.*
>
> . . . .
>
> ***KROFT: (voiceover)*** *Reardon, who is now an investigator with the Food and Drug Administration, says he was told who to interview and what questions he could and couldn't ask.*
>
> *Has that ever happened before?*
>
> ***Mr. REARDON:*** *Not in my career.*
>
> ***KROFT:*** *What did you make of it?*
>
> ***Mr. REARDON:*** *That somebody didn't really want the truth coming out.*[46]

The Select Committee conducted an investigation of these allegations. However, the Justice Department has requested that the Select Committee not disclose the details of its investigation to protect the Justice Department's prosecution of CATIC and McDonnell Douglas.

On February 5, 1996 *U.S. News and World Report* reported that the machine tools had been diverted, and that an investigation was underway. The Commerce Department received inquiries from then-Chairman Alfonse M. D'Amato of the

Senate Committee on Banking, Housing and Urban Affairs, and from Chairman Benjamin A. Gilman of the House Committee on International Relations, concerning these reported allegations.[47] Subsequently, Chairman Floyd D. Spence of the House Committee on National Security and Representative Frank Wolf asked the General Accounting Office to review the facts and circumstances relating to the licensing and export of the machine tools. The results of the General Accounting Office review are summarized earlier in this chapter.[48]

The February 5, 1996 *U.S. News and World Report* also claimed that "a confidential U.S. Commerce Department investigative report" had been obtained and used in the article. Concerned that the disclosure of such a report to *U.S. News and World Report* may have violated the confidentiality provisions of Section 12 (c) of the Export Administration Act, the Office of Export Enforcement initiated an internal inquiry. Responsibility for the disclosure was never determined.

The Office of Export Enforcement's Los Angeles Field Office's Request for a Temporary Denial Order Against CATIC

Under the provisions of Part 766.24 of the Export Administration Regulations (EAR), the Assistant Secretary for Export Enforcement is authorized to issue a Temporary Denial Order (TDO):

> *. . . upon a showing by [the Bureau of Export Enforcement] that the order is necessary in the public interest to prevent an imminent violation of the [Export Administration Act], the [Export Administration Regulations], or any order, license or authorization issued thereunder.*[49]

In late November 1995, the Los Angeles Field Office requested that the Commerce Department issue a TDO against CATIC.[50] The TDO request was prepared as a means to compel CATIC to comply with the terms of the machine tool export licenses by preventing the approval of future export licenses.

The Commerce Department declined to issue the TDO. In a December 7, 1995 memorandum, the Office of Export Enforcement Headquarters returned the TDO case report because it contained a number of technical deficiencies, including:

- **Did not include licensing determination for each commodity that was exported.** Licensing determinations were necessary elements of proof that the commodities required a license to be exported.
- **Did not include any documentary evidence such as shipping and export control documents** to confirm that the exports had occurred.
- **Did not include a schedule** of violations that described the specific violations that allegedly had occurred.
- **Did not use the proper form and format** that Office of Export Enforcement regulations specified in the Office's Special Agent Manual.

Headquarters, noted, however, that "the violations do appear to be deliberate and substantial." It instructed the Los Angeles Field Office to give the investigation a high priority. Moreover, it instructed them to conduct additional interviews and to obtain relevant documentation.

The Los Angeles Field Office was concerned that Headquarters was using those technical deficiencies as a bureaucratic rationale for not seeking Commerce Department approval of the TDO request.

At the date of the Select Committee's Final Report (January 3, 1999), the Office of Export Enforcement and the U.S. Customs Service reportedly are continuing to investigate the machine tool diversion under the direction of the U.S. Attorney for the District of Columbia.

The PRC's Diversion of the Machine Tools

CATIC Letter Suggests Trunkliner Program at Risk

In a September 30, 1993 letter to McDonnell Douglas Aircraft Company President Robert Hood, CATIC Vice President Tang Xiaoping expressed concerns that negotiations were at an impasse for CATIC's purchase of the machine tools and other equipment.[51] The letter seemed to suggest that the Trunkliner Program would be at risk if a deal could not be worked out. According to the letter:

. . . I think for sure, whether or not this procurement project will be successful shall have a big influence on the trunk liner programme [sic] and long term cooperation between [Aviation Industries Corporation of China] and [McDonnell Douglas]. . .

McDonnell Douglas characterized Tang Xiaoping's letter as nothing more than a negotiating ploy to try to get McDonnell Douglas to lower the price that it was asking for the machine tools. McDonnell Douglas officials said they did not consider the letter to be a veiled threat by CATIC to cancel or alter the Trunkliner Program if a deal for the machine tool equipment could not be worked out.

According to the Defense Department, however, CATIC had a longstanding, productive relationship with McDonnell Douglas, had made major investments in the Trunkliner Program, and was not going to jeopardize those investments and the Trunkliner Program in a dispute over the price of used machine tools.

Indeed, the purchase price that was eventually agreed to between McDonnell Douglas and CATIC was acceptable to both parties. The value of the machine tools was based upon an appraisal provided by a commercial auctioneer. McDonnell Douglas added a 20-30 percent markup. CATIC acquired all of the machine tools it had originally sought, as well as various other tools, equipment, furniture and other items as part of the $5.4 million purchase agreement.

The machine tools and other equipment purchased by CATIC were excess to McDonnell Douglas's needs. According to McDonnell Douglas, the more modern machine tools and equipment from the Columbus, Ohio plant were not sold to CATIC but were redistributed to other McDonnell Douglas facilities.

According to the March 1, 1994 appraisal, the value of 31 machine tools sold to CATIC — including the 19 machine tools that required export licenses — was $3.5 million.[52] This appraisal did not assess the value of other tools, equipment, and furnishings that were included as part of the purchase agreement.

CATIC's Efforts to Create the Beijing Machining Center with Monitor Aerospace

Doug Monitto was the President of Monitor Aerospace Corporation, an Amityville, New York-based company that manufactured aircraft components. In the fall of 1993, Monitto met with CATIC representatives in the PRC to discuss joint venture opportunities.

During those discussions, CATIC expressed an interest in subcontracting with Monitor Aerospace for the production of aircraft parts. Specifically, Monitor would assist the PRC in the production of certain aircraft parts that CATIC was to manufacture for Boeing as part of an offset contract.

Monitto says he proposed that CATIC convince Boeing to transfer $10 million of the offset work directly to Monitor for one year. During that year, Monitor Aerospace would assist CATIC in designing and laying out a new machining center.[53] Thereafter, CATIC itself, with Monitor's assistance, could provide all subsequent manufacturing for the Boeing parts.

Representatives of CATIC, Aviation Industries of China, and Monitto signed a Memorandum of Understanding (MOU) regarding the machining center joint venture on January 24, 1994.[54] CATIC officials took Monitto to an industrial park in Beijing where the machining center was to be built.

In a letter dated January 27, 1994, CATIC informed Boeing that it had signed the joint venture MOU, and asked if Boeing would consider providing Monitor Aerospace with the offset work.[55] However, Boeing, in an April 1994 letter, declined CATIC's offer.[56]

In the spring of 1994, Monitto says CATIC officials again approached him about a machining center joint venture.

Although negotiations were intermittent, Monitto says CATIC informed him in the summer of 1994 that it had purchased machine tools from McDonnell Douglas. As Monitto recalls, CATIC officials asked for his assistance in reassembling the machine tools, and placing them in a machining center. However, he says the precise location of the machining center had not been determined at that time.[57]

A July 29, 1994 letter from Monitto to Sun Deqing, CATIC's Deputy Director, states:

> *As a result of your visit we have prepared an alternative approach that will help us achieve our mutually desired goal of building a "State of the Art" profile milling machine shop in China.*
>
> *Monitor Aerospace would like to offer its assistance to CATIC in entering this new marketplace as both a partner and as a technical expert in the field.*
>
> *The most significant feature of this new approach would be the fact that Monitor would also be the launch customer of the new joint venture.*[58]

Additional discussions between CATIC and Monitor Aerospace regarding establishing the machining center appear to have continued into the fall of 1994, after the export licenses for the McDonnell Douglas machine tools had been approved.

According to a September 23, 1994 letter to CATIC's Sun Deqing, Monitto proposed that, as part of a joint venture to manufacture aircraft parts in the PRC, CATIC would:

> *. . . supply an appropriate building located in the Beijing-Tianjin metropolitan area which permits growth. CATIC will provide other necessary infrastructure and planning support, including arranging for appropriate utility hook-ups, tax concessions, customs clearance, etc.*[59]

Sometime in the fall of 1994, Monitto recalls that CATIC informed him that it intended to place the McDonnell Douglas machine tools at a facility located in the city of Shijiazhuang. Monitto drove to the facility to check out the offer but decided the location was too far from his base of operations in Beijing to be viable. It was "not something I wanted to do," Monitto comments.[60]

According to Monitto, he has had no further substantive discussions with CATIC regarding the establishment of a machining facility, although he does remain in contact with CATIC on other business-related matters. According to Monitto, McDonnell Douglas was never a party to any of his negotiations with CATIC regarding the establishment of the machining center.[61]

According to McDonnell Douglas, the first indication it had that CATIC would not establish the machining center took place during a phone call with a CATIC official in May 1995. Subsequently, in a letter dated July 5, 1995, CATIC Supply Vice President Zhang Jianli formally advised McDonnell Douglas that an agreement could not be reached with Monitor Aerospace for a machining center, and that Nanchang Aircraft Factory was interested in purchasing the six machine tools that were stored at that factory.

According to the letter:

> *You were aware that we planned to set up a joint venture with Monitor Aerospace, which would be the enduser [sic] in applying [for] the license. Unfortunately both sides couldn't reach agreement. Without this agreement we muse [sic] find other uses or purchasers in China.* [62]

According to McDonnell Douglas, it believed that CATIC was serious in its plans to build a machining center in Beijing to produce airplane parts for the Trunkliner Program.

McDonnell Douglas acknowledges, however, that it never asked for, nor was it shown, architectural drawings, floor plans, or other information to indicate that plans for the facility were progressing.

Diversion of the Machine Tools to Nanchang Aircraft Company

When the machine tools arrived in the PRC, McDonnell Douglas personnel discovered that nine of the machines were stored at two different locations in the port city of Tianjin.[63]

Moreover, a March 27, 1995 letter from Zhang Jianli, the Vice President of CATIC Supply Company, to McDonnell Douglas's Beijing office explained that six more of the machine tools had been shipped to Nanchang for storage. These machine tools, CATIC represented, remained in their crates.[64]

Two McDonnell Douglas representatives visited Nanchang to inspect the tools on August 23, 1995 and learned that one of the machine tools — a hydraulic stretch press — had been uncrated and was situated inside a building. Moreover, the building had been built *specifically to accommodate that piece of equipment.*

Although electrical power had not yet been connected,[65] the size of the building and the manner of its construction suggested to them that this facility had been custom built to house McDonnell Douglas equipment, and had been planned for several years:

- **Possibly as early as December 23, 1993,** when CATIC and McDonnell Douglas signed an agreement for the purchase of machine tools and other equipment from McDonnell Douglas's Columbus, Ohio plant
- **Perhaps even as early as late 1992,** when CATIC first expressed interest in the purchase

CATIC (USA) documents[66] indicate that an official of "TAL Industries" was primarily responsible for supervising the PRC team that coordinated and supervised the packing and crating of the machine tools and other equipment at the Columbus, Ohio plant.[67] According to its responses to a series of Select Committee interrogatories, TAL Industries is a subsidiary of CATIC Supply in the PRC. CATIC Supply, in turn, is a wholly-owned subsidiary of CATIC.[68] According to TAL Industries, CATIC Supply owns 90 percent of its stock, and CATIC (USA) owns the remaining 10 percent.[69] TAL Industries is located at the same El Monte, California address and has the same telephone number as CATIC (USA).[70]

Some of the McDonnell Douglas equipment had been sold or given by CATIC to the Nanchang Aircraft Company. At least some of these transfers of ownership must have occurred before any of the equipment was exported from the United States. In addition, the PRC team that coordinated the disassembly and packing of the equipment at the Columbus, Ohio plant included representatives from the Nanchang Aircraft Company, who apparently were responsible for overseeing the packing of the equipment it was obtaining from CATIC.

Internally, CATIC specifically referenced the cargo as Nanchang's equipment.

Separately, the Nanchang Aircraft Company's Technology Improvement Office submitted inquiries to CATIC concerning the location of various pieces of its—Nanchang's—equipment.

Since most of the Columbus, Ohio equipment that was purchased by CATIC did not require an export license,[71] CATIC's subsequent sale of that equipment to Nanchang Aircraft Company would not violate U.S. export controls.[72] But the CATIC (USA) documents pertaining to Nanchang Aircraft Company's equipment do not explicitly identify the equipment, including the six machine tools that were later found at the Nanchang Aircraft Factory in violation of the export licenses.[73]

Nanchang Accepts Responsibility

In a September 13, 1995 letter to McDonnell Douglas China Program Manager Hitt, the Vice President of the Nanchang Aircraft Company accepted full responsibility for uncrating and installing the hydraulic stretch press in a newly constructed building. According to the letter:

> *Now I would like to review the detail and apologize for the result caused by the action we made. The following is the reason why we put the [hydraulic stretch] press into the pit.*
>
> *When we heard that the agreement had not been made between CATIC and Monitor [Aerospace] concerning the cooperation. [sic] We expressed our intention to CATIC that we would like to buy some of the machines and at that time CATIC also intended to sell to us.*
>
> *But they mentioned to us for several times that the cases can not be unpacked until the amendment of enduser [sic] is gained from the Department of U.S. Commerce. We do not think that there is any problem to get the permission for the second hand press, which has not got new technology because we have the experience that when we import the press from [a foreign manufacturer of machine tools].*

> *Under this guidance of the thought, we started to prepare the fundation [sic] in order to save time.*[74]

The letter went on to argue that, because of its size, the hydraulic stretch press had to be uncrated in order to move it to Nanchang from its port of entry in Shanghai. Moreover, the stretch press had then been moved into the "pit" that it would occupy so the new building *could be built around it*. To do otherwise, the PRC letter said, would have disrupted the construction of the new building.[75]

The Nanchang Aircraft Company official also apologized for the events that had occurred, and provided assurances that no further installation of the hydraulic stretch press would take place at the Nanchang Aircraft Factory until permission to do so was given by the U.S. Government.[76]

A July 5, 1995 letter to McDonnell Douglas China Program Manager Hitt from CATIC Supply Vice President Zhang Jianli reflects CATIC's knowledge that prior U.S. Government approval for the transaction was required. According to the CATIC Supply letter:

> *Nanchang Aircraft Factory is very much interested in 6 sets of the equipment. We would like to sell to them if we are allowed to do so because we understand that the licenses are only good for the Beijing machining center as it was approved originally.*
>
> *Is it possible to request the United States Commerce department [sic] to approve selling the machines to Nanchang Aircraft Company? The machines are being stored there now,* ***and they are required not to be unpacked until we receive approval*** *from the Department of Commerce of the U.S.A.*[77] [Emphasis added]

When Hitt and a colleague visited the Nanchang Aircraft Company on August 23, 1995, the Nanchang Aircraft Company officials informed them that one of the machine tools delivered to Nanchang had been placed inside a building "to protect it from the elements."

At the insistence of McDonnell Douglas's Hitt, the PRC officials took him to the building, where he found a hydraulic stretch press installed in a building that appeared to have been specifically built for it. The building had actually been *built around* the hydraulic stretch press, since Hitt observed no openings or doorways that were large enough to have allowed the machine tool to be moved into the building from elsewhere. Parts for the machine were strewn about the building in such a manner as to indicate that efforts were underway to reassemble the machine and restore it to operational condition. Although electrical power had not been connected to operate the stretch press, trenches for the power cables had been dug and other electrical work had been completed.

Hitt says the storage explanation he originally was given by Nanchang officials was, without question, disingenuous.

Concerned over Hitt's expressions of anger at seeing the partially installed stretch press, Hitt says Nanchang officials tried to reassure him that they only intended to use the stretch press for civilian production at the factory.

Since early 1996, the McDonnell Douglas machine tools have been stored at Shanghai Aviation Industrial Corporation (SAIC).

CHRONOLOGY OF KEY EVENTS

1992

March 28 — **McDonnell Douglas and CATIC sign contract** to co-produce 20 MD-82 and 20 MD-90 series commercial aircraft in the PRC.

1993

September — **Informants tell Defense Technology Security Administration** that PRC nationals are regularly visiting McDonnell Douglas's Columbus, Ohio plant. Concerned that the visits may constitute illegal technology transfer, DTSA contacts U.S. Customs Service.

September 30 — **Letter from CATIC Executive Vice President Tang Xiaoping** to McDonnell Douglas Aircraft Company President Robert Hood suggesting that McDonnell Douglas's failure to sell machine tools to CATIC could have a "big influence" on Trunkliner Program.

October 13 — **U.S. Customs Service agent** visits Columbus, Ohio plant. Following interviews with McDonnell Douglas officials, U.S. Customs Service agent reports that no further investigative action is contemplated.

December 23 — **CATIC and McDonnell Douglas reach agreement** on sale of machine tools and other equipment from McDonnell Douglas's Columbus, Ohio plant, and four machine tools located at Monitor Aerospace, in Amityville, New York. Included are 15 machine tools that require individual validated licenses.

1994

January 24 — **Memorandum of Understanding for CATIC Machining Center joint venture** signed by Monitor Aerospace, CATIC, and Aviation Industries of China.

February 15	**CATIC officials sign purchase agreement** for machine tools and other equipment at McDonnell Douglas's Columbus, Ohio plant.
March	**Disassembly, packing and crating of McDonnell Douglas machine tools** and other equipment begins at Columbus, Ohio plant.
Spring	**Defense Technology Security Administration** learns that manufacturing equipment at McDonnell Douglas's Columbus, Ohio plant has been exported to the PRC. U.S. Customs Service is informed.
May 26	**McDonnell Douglas applies** for machine tool export licenses.
June 7	**McDonnell Douglas briefs** Commerce, State, and Defense Department representatives on Trunkliner Program and CATIC Machining Center.
June 23	**McDonnell Douglas again briefs** interagency meeting on Trunkliner program and CATIC Machining Center.
June 24	**Machine tool license applications discussed at Advisory Committee for Export Policy (ACEP) meeting.** Defense Department cautions against rushing to approve licenses pending further review. No decision reached.
July 26	***Flight International* article reports only 20 McDonnell Douglas aircraft to be built in the PRC,** with the remaining 20 to be built in the United States.
July 28	**ACEP meeting again discusses machine tool licenses.** Decision deferred until next ACEP meeting.

August 25	**ACEP meeting minutes indicate export licenses for the machine tools were approved** prior to this ACEP meeting.
August 29	**State Department asks U.S. Embassy/Beijing to obtain end use assurance** for machine tools from senior CATIC official.
Late August	**Commerce Secretary Ronald Brown** leads trade mission to the PRC.
September 13	**U.S. Embassy/Beijing reports that it obtained CATIC end use assurance** and advises that final location of the machining center has not been determined.
September 14	**Department of Commerce formally issues export licenses** to McDonnell Douglas for 19 machine tools.
October	**Construction** of machining center was reportedly to begin.
November 4	**CATIC and McDonnell Douglas sign amended contract** reducing the number of aircraft to be built in the PRC from 40 to 20, with the remaining 20 to be built in the United States.
November/ December	**Most of Columbus, Ohio machine tools** are shipped to the PRC.

1995

February	**Remaining Columbus, Ohio machine tools are shipped to the PRC.** Four machine tools still remain at Monitor Aerospace in Amityville, New York.
March 24	**McDonnell Douglas representative inspects** nine machine tools in original shipping crates at two locations in Tianjin, a port city

two hours drive from Beijing. McDonnell Douglas's Beijing office letter to CATIC requests information on machine tools not found in Tianjin.

March 27	**CATIC letter to McDonnell Douglas's Beijing office assures** that six machine tools remain packed and in storage in Nanchang.
April 4	**McDonnell Douglas letter to the Department of Commerce reports location of machine tools** and notes that six of the machine tools are reportedly located at Nanchang Aircraft Company, four remain at Monitor Aerospace in Amityville, New York, and the remainder are stored at two locations in Tianjin.
April 20	**McDonnell Douglas briefs interagency meeting on locations of machine tools.** Commerce Department Office of Export Enforcement representative is present at meeting, and determines that no active investigation is warranted.
Late April/ Early May	**In telephone call with McDonnell Douglas China program manager, CATIC official says no agreement** could be reached with Monitor Aerospace for creation of the machining center. The Department of Commerce is informed.
May 15	**The Department of Commerce instructs McDonnell Douglas to arrange for the six machine tools at Nanchang to be shipped** to and consolidated with the nine machine tools at Tianjin. The Department of Commerce informs McDonnell Douglas that it has revoked the export licenses for the four machine tools at Monitor Aerospace in Amityville, New York.
June 1	**In a letter to CATIC, McDonnell Douglas requests CATIC take immediate action** to consolidate all machine tools at one location in Tianjin, and informs CATIC that the Commerce Department has cancelled the export licenses for the four machine tools in Amityville, New York.

July 15	**Letter from CATIC to McDonnell Douglas confirms that no agreement could be reached** with Monitor Aerospace to build the machining center, and that Nanchang Aircraft Factory was interested in purchasing six machine tools. The letter asks McDonnell Douglas to obtain U.S. Government approval for that transaction.
August 1	**McDonnell Douglas applies for Commerce Department licenses** to allow six machine tools to remain at the Nanchang Aircraft Factory.
August 23	**During a visit to the Nanchang Aircraft Factory, McDonnell Douglas representatives discover** the hydraulic stretch press uncrated and situated in a partially completed custom building designed and built around it.
September 28	**Commerce Department informs McDonnell Douglas** to remain at Nanchang Aircraft Factory.
October	**McDonnell Douglas requests amended export licenses to allow the machine tools** at Tianjin and Nanchang to be moved to Shanghai Aviation Industrial Corporation for use in the Trunkliner program.
November 7	**Commerce Department's Office of Export Enforcement opens investigation** of the machine tool diversion.
November 28	**The Office of Export Enforcement Los Angeles Field Office asks the Commerce Department to issue a Temporary Denial Order against CATIC.**
December 7	**Office of Export Enforcement denies the request** for a Temporary Denial Order against CATIC.

December	**CATIC Machining Center in Beijing was reportedly to start** producing Trunkliner parts.

1996

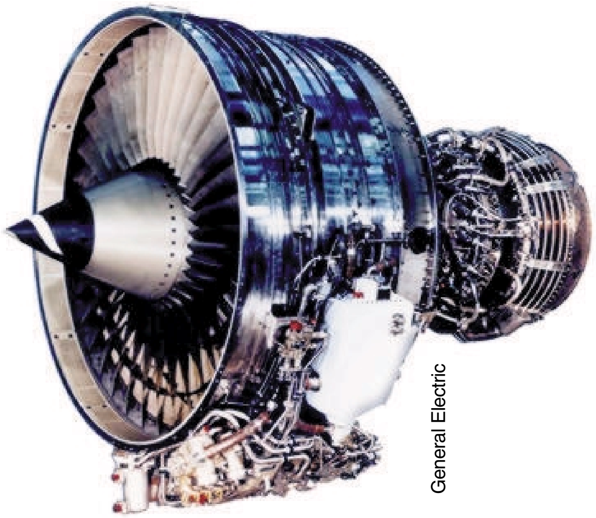
January 31	**Commerce Department is informed that five of the six Nanchang machine tools have arrived** at the Shanghai Aviation Industrial Corporation. The hydraulic stretch press remains at Nanchang.
February 6	**Amended licenses are approved by Commerce Department** to permit the machine tools to be used by the Shanghai Aviation Industrial Corporation.
Late Winter/ Early Spring	**U.S. Customs Service joins** machine tool investigation.
April 23	**U.S. Embassy official visits Shanghai Aviation Industrial Corporation** and examines the machine tools from Tianjin.
June 21	**Portions of the hydraulic stretch press** from Nanchang are reported to be at Shanghai.
July	**Marc Reardon, the Commerce Department Los Angeles Field Office case agent for the machine tool investigation, resigns.**
August 5	**The remaining parts of the hydraulic stretch press** from Nanchang are reported to be at Shanghai.

PRC Targeting of U.S. Jet Engines And Production Technology

The PRC's acquisition of aerospace and defense industrial machine tools from U.S. and foreign sources has expanded its manufacturing capacity and enhanced the quality of military and civilian commodities that the PRC can produce.[78]

These acquisitions will support the PRC's achievement of a key goal: the development of an aerospace industrial base that is capable of producing components and structural assemblies for modern manned aircraft and cruise missiles.[79]

To meet combat mission requirements, modern military aircraft and cruise missiles require advanced jet engine systems.[80] The PRC does not have an indigenous production capability for advanced jet engines. Thus, acquiring such a capability has been a national priority for the PRC throughout the 1990s.[81] Development of new commercial and military jet engines is also a priority. The PRC is also likely to be focused on production of jet engines similar to those used for both commercial aircraft and for cruise missiles.


General Electric

In 1983, the PRC legally acquired two GE CFM-56 jet engines, ostensibly for a civil aircraft program. The PRC later claimed that the engines were destroyed in a fire. More likely, the PRC reverse engineered part of the CFM-56 to develop a variant for use in military combat aircraft.

The PRC's activities indicate that Beijing has a particular interest in the acquisition of jet engine production technologies and equipment from U.S. sources. Moreover, the PRC has reportedly sought to compensate for shortfalls in its indigenous capabilities by acquiring complete jet engines from U.S. sources.[82]

In the mid-1980s and early 1990s, the PRC apparently adopted a three-track approach to acquiring U.S. equipment and technologies in order to advance its own military jet engine capabilities:

- **The diversion of engines from commercial end uses**
- **Direct purchase**
- **Joint ventures for engine production**

The PRC's acquisition targets suggest that it planned to acquire several families of jet engines that could be adapted to various military and commercial applications.[83]

The PRC has been particularly interested in acquiring "hot section" technology from U.S. sources.[84] The United States is the world leader in hot section technology for turbojets and turbofan engines. As a result, U.S. military aircraft can outlast and outperform foreign-built military aircraft.[85] In this regard, the PRC seeks:

> *Technology such as materials and coatings inside the turbine that can withstand extreme heat and associated cooling systems, and could be used to increase power and durability of Chinese aero-engine designs.*[86]

In 1983, the PRC legally acquired two General Electric CFM-56 jet engines, ostensibly to analyze the engines for a potential civil aircraft upgrade program. In the course of the export licensing process, the Defense Department insisted on restricting the PRC's use of the engines. Under the terms of the licensing agreement:

> *No technical data was to be transferred with the engines; the Chinese were not to disassemble the engines; and finally, if the Trident [civil aircraft] retrofit program had not begun within 1 year of the engines' arrival, the engines were to be repurchased by the manufacturer. In addition, the Chinese offered to retrofit*

engines at a Shanghai commercial aircraft facility where GE personnel would be able to monitor Chinese progress.[87]

Defense Department officials were concerned because the CFM-56 hot sections are identical to those used in the engines that power the U.S. F-16 and B-1B military aircraft.[88]

The PRC later claimed that the CFM-56 engines were destroyed in a fire.[89] More likely, however, is that the PRC violated the U.S. end-use conditions by reverse engineering part of the CFM-56 to develop a variant for use in combat aircraft.[90]

Despite the suspected reverse engineering of the two General Electric jet engines that were exported in 1983, G.E. reportedly signed a contract in March 1991 with the Shenyang Aero-Engine Corporation for the manufacture of parts for CFM-56 engines.[91] According to one source, Shenyang "put in place quality and advanced manufacturing systems to meet US airworthiness standards."[92]

The PRC aggressively attempted to illegally acquire General Electric's F404 engine, which powers the U.S. F-18 fighter.[93] The PRC likely intended to use the F404 jet engine in its F-8 fighter.[94] The PRC succeeded in acquiring some F404 technology through an indirect route by purchasing the LM-2500, a commercial General Electric gas turbine containing the F404 hot section.[95]

In addition, G.E. has reportedly proposed a joint venture with the PRC to manufacture the so-called CFM-56-Lite. The engine could power the PRC's planned AE-100 transport.[96]

The PRC also has targeted large engines for aerospace and non-aerospace applications. The PRC's acquisition plans reportedly include Pratt & Whitney JT-8 series engines and technology to support its large aircraft projects, as well as marine derivatives of the G.E. LM-2500 for naval turbine propulsion projects.[97] Regarding the JT-8 series:

> *In August 1986, CATIC licensed the technology for the U.S. Pratt and Whitney FT8 gas turbine engine, including joint development, production and international marketing rights. The FT8 is a development of the JT8D-219 aero-engine (used to power Boeing 727, Boeing 737, and MD-82 aircraft), and can produce 24,000 kW (33,000 hp). [It] represented another significant technical leap for China's gas turbine capability . . . Chinese students were also sponsored by Pratt and Whitney for graduate level aerospace training in the United States.*[98]

The PRC's efforts to acquire compact jet engines can be traced to 1965, when the Beijing Institute of Aeronautics and Astronautics launched a project to copy the U.S. Teledyne-Ryan CAE J69-T-41A (*depicted at right*).[99]

The Teledyne-Ryan J69, jet engine, which the PRC copied in the 1960s.

The Teledyne engine powered the U.S. Air Force AQM-34N Firebee reconnaissance drone, a number of which were shot down over the PRC during the Vietnam conflict.[100]

The jet engine for the U.S. Air Force AQM-34N Firebee reconnaissance drone, a number of which were shot down over the PRC during the Vietnam War, was copied by the PRC and currently is used in PLA cruise missiles.

The PRC's copy of the U.S. turbojet, dubbed WP-11, began ground testing in 1971 and currently powers the PLA's HY-4 "Sadsack," a short-range anti-ship cruise missile.[101]

The PRC began work on cruise missile engines in the 1980s. The PRC's interest in developing long-range cruise missiles increased dramatically after the 1991 Persian Gulf War, when the performance of U.S. Tomahawk cruise missiles demonstrated the effectiveness of precision missile strikes using conventional warheads. However, technical challenges slowed Beijing's efforts. For this reason, the PRC has attempted to acquire foreign-built engines for technical exploitation. If the PRC succeeds in building cruise missile propulsion and guidance systems, then it would probably not have difficulty marketing cruise missiles to third world countries.[102]

In 1990, the PRC attempted to advance its cruise missile program by purchasing the Williams FJ44 civil jet engine (*depicted at right*).[103] This compact turbofan was derived from the engine that powers the U.S. Tomahawk cruise missile (*shown below*).

Williams FJ44

Associated Press

A year after the PRC had attempted to advance its cruise missile program by purchasing the Williams FJ44 civil jet engine, the 1991 Persian Gulf War impressed the PRC with how long-range cruise missiles like the U.S. Tomahawk, being fired in the photo above, could strike their targets with precision.

The FJ44 engine might have been immensely valuable to the PRC for technical exploitation and even direct cruise missile applications.[104] But the PRC's effort to acquire FJ44 engines was rebuffed.[105]

CASE STUDY: Garrett Engines

The redundancy inherent in the PRC's three-track approach to advancing its military jet engine capabilities — diversion of engines from commercial use, direct purchase, and joint ventures — began to bear fruit in the early 1990s.[106]

The Cold War's end and a liberalization of Cold War-era export controls on dual-use products and technologies opened new opportunities for the PRC to acquire advanced jet engines and production capabilities. A notable opportunity developed in 1991 when, as part of an overall liberalization of export controls by the Coordinating Committee for Multilateral Export Controls (COCOM), the Commerce Department decontrolled a popular jet engine manufactured by Allied Signal's Garrett Engine Division.

Prior to 1991, the Garrett engine required an individual validated license that included restrictive conditions.

The Commerce Department's decision that Garrett jet engines were decontrolled ensured that they could be exported to the PRC without a license or U.S. Government review. The decision also opened the way for a jet engine co-production arrangement sought by the PRC.

Negotiations for a co-production deal between Allied Signal and PRC officials progressed until July 1992, when the Defense Department learned of the plan.[107] The Defense Department's reaction to the news sparked an interagency review of the Commerce Department's decision to decontrol the Garrett engines.

The co-production deal was terminated after the review demonstrated the potential national security implications of transferring jet engine production capabilities to the PRC.[108]

PRC Targeting of Garrett Engines

The PRC's reported motivation for initiating the Garrett engine purchase was the PRC's requirement for a reliable, high-performance Western engine for its developmental K-8 military aircraft.[109]

The K-8, depicted below, is a multi-role aircraft that can serve as a trainer, fighter, or light ground attack bomber.[110] The K-8 project was initiated by the PRC around 1987, and later became a joint effort with Pakistan.

Janes Defense Group

Beijing has a particular interest in the acquisition of jet engine production technologies and equipment from U.S. sources. The PRC's reported motivation for initiating the purchase of Garrett engines was its need for reliable, high-performance power plants for its developmental K-8 military aircraft (shown here in Pakistani liverage). In addition to serving as a trainer, it can be used as a fighter jet or light ground-attack bomber.

PRC aerospace organizations involved in the project included:

- **China National Aero-Technology Import-Export Corporation (CATIC)**
- **China Nanchang Aircraft Manufacturing Company**
- **China National South Aero-Engine and Machinery Company**[111]

The PRC's access to the Garrett TFE-731 *(depicted below)* may have influenced its choice of small jet engines in general, and K-8 propulsion in particular. The PLA purchased a fleet of Learjets from the U.S. on the understanding that the aircraft would be for civil use. It is suspected, however, that the PLA diverted both the aircraft and the engines for military purposes, including PLA reconnaissance missions.[112]

The Garrett TFE-731 jet engine sought by the PRC was determined by the Department of Defense not to be a derivative of an older civilian-use engine, but rather a substantially improved power plant used in military aircraft such as the Spanish-manufactured CASA C-101 attack jet.

U.S. Government Approval of the Initial Garrett Engine Exports

In August 1989, Allied Signal applied for an export license to sell a variant of the TFE-731, the TFE-731-2A-2A, to the PRC. Four engines and spare parts were to be shipped.[113] The U.S. Federal Aviation Administration (FAA) had certified the TFE-731-2A-2A as a "civil" engine.[114]

According to Iain S. Baird, then-Deputy Assistant Secretary of Commerce for Export Administration, the Commerce Department had licensing authority for the civil engine regardless of its military (i.e., the PLA's K-8 military aircraft) application.[115]

The 1989 application for the export of the Garrett engines to the PRC raised concerns among officials at the Defense Technology Security Administration, which was the focal point for export policy guidance and license reviews within the Defense Department.[116]

A Defense Technology Security Administration technical analysis, for instance, indicated that the TFE-731-2A-2A had "some design and manufacturing technical data … common to the … TFE1042 and TFE1082," both of which are combat aircraft engines.[117]

Given this Defense Department judgment, a condition was placed by the Commerce Department on the export license for the TFE-731-2A-2As:

> ***"There is to be no transfer of engine design or manufacturing technical data provided with this transaction."*** [Emphasis added][118]

The case was also reviewed by COCOM. Subsequently, the Commerce Department issued an Individual Validated License (number D032648) for the Garrett engines on May 30, 1990.[119]

In December 1990, Allied Signal asked the Commerce Department for approval to sell an additional 15 of the TFE-731-2A-2A engines to the PRC.[120]

These engines were reportedly to be used for the first production run of the PLA's K-8 military aircraft, which were to be sold to Pakistan. The Defense Department and COCOM again reviewed the license application, and Defense requested conditions that would forbid the release of TFE-731-2A-2A "design methodology, hot section repair/overhaul procedures and manufacturing information."[121]

On June 12, 1991, the Commerce Department granted Individual Validated License D130990, which included the Defense Department's recommended conditions.[122]

Commerce Department Decontrol of the Garrett Jet Engines

In August 1991, Allied Signal requested that the FAA re-certify the TFE-731-2A-2A engine with a digital electronic engine controller.[123] The FAA had certified the engine in 1988 with an analog engine controller.[124]

It is unclear from the available information whether the PRC requested this upgrade of the engine to include the digital electronic engine controller, or whether Allied Signal decided to upgrade the engine on its own initiative.[125]

On September 1, 1991, the Commerce Department published revisions to the Export Administration Regulations to reflect liberalized export controls that had been agreed to by the United States and its COCOM partners.[126] The revised regulations decontrolled many jet engines, but continued to control exports of engines equipped with full authority digital engine control (FADEC) systems.[127]

These militarily-sensitive systems control jet engine operations to permit, among other things, maximum propulsion performance for manned and unmanned military air vehicles.[128]

According to Defense Department records, Allied Signal sent a one-page document to the Commerce Department on September 30, 1991 representing that the TFE-731-2A-2A did not use a FADEC system, but instead used a less capable digital electronic engine controller (DEEC). For this reason, Allied Signal officials believed the TFE-731-2A-2A was completely decontrolled under the revised Export Administration Regulations and COCOM controls.[129]

Technical experts at the Defense Technical Security Agency had already presented their analysis to Commerce Department officials, countering that the TFE-731-2A-2A contained a FADEC and therefore remained controlled under COCOM and U.S. regulations.[130]

On October 1, 1991, one day after receiving the Allied Signal document regarding the FADEC issue, the Commerce Department ruled that the TFE-731-2A-2A did not contain a FADEC. The Commerce Department then informed Allied Signal's Garrett Engine Division that it could export TFE-731-2A-2A jet engines to the PRC under a General License (a so-called G-DEST license) pursuant to the Export Administration Regulations, as long as production technology was not transferred.[131]

Defense Department records indicate that officials at the Defense Technology Security Administration concurred with the Commerce Department decision to permit this export, but mistakenly believed it was still under an Individual Validated License arrangement — that is, with the requested Defense Department conditions.[132]

Subsequently, the Commerce Department amended the October 1, 1991 decision and notified Allied Signal on November 25, 1991 that it had decontrolled the TFE-731-2A-2A entirely.[133]

Engine production technology could now be exported to the PRC without a license.[134] According to Defense Department records, Commerce Department officials relied exclusively on Allied Signal's September 30, 1991 representation concerning the engine controller for the TFE-731-2A-2A — that is, that the controller was not a FADEC, and thus was no longer controlled.[135]

Bruce C. Webb, then a senior analyst at the Commerce Department's Office of Nuclear Controls, recalls that a U.S. Government advisory group had reviewed the Allied Signal document and agreed with the company's assertion that the TFE-731-2A-2A was not equipped with an embargoed FADEC.[136] However, in response to document requests by the Select Committee, the Commerce Department was unable to provide any records of any technical reviews that it may have conducted.[137]

The Interagency Review of the Proposed Export of Garrett Engines

Iain Baird, then-Deputy Assistant Secretary of Commerce for Export Administration, claims that the Commerce Department coordinated with appropriate agencies before making the General License determination in November 1991. However, the Commerce Department was unable to provide the Select Committee with any documentary evidence to this effect.[138]

A Defense Technology Security Administration staff member suggests that other agencies learned of the decision by chance, or "dumb luck."[139] In addition, according to a December 29, 1992 Defense Department memorandum for the record:

> *Commerce approved, with DoD and CoCom concurrence, the sale of 15 Garrett TFE-731-2A-2A engines to the PRC for incorporation into military trainers being exported to Pakistan.*
>
> *In July 1992 DTSA [the Defense Technology Security Administration] learned from cable traffic that the PRC and Garrett were negotiating an arrangement to coproduce this engine in China for use in PLA military trainers.*
>
> *We learned shortly thereafter that Department of Commerce had determined in November 1991 that the engine did not require an Individual Validated License (IVL) for shipment to the PRC.*
>
> *Department of Commerce, without consulting with Department of Defense, classified the engine and technology decontrolled (or "G-DEST") under the CoCom Core List implemented on 1 September 1991.*
>
> *DTSA believes the export requires an IVL [Individual Validated License].*[140]

After receiving a copy of the July 1992 cable, the Defense Technology Security Administration initiated an interagency review of the Commerce Department General License decision regarding the Garrett engines.[141] The Commerce Department agreed to suspend its decision pending the outcome of the review.

Officials at the Defense Technology Security Administration reportedly were especially concerned over any transfer of jet engine production technology to the PRC. They were also surprised that the Commerce Department opted not to coordinate its decision, given the agency's oft-repeated concerns over any transfer of jet engine production technology to the PRC.[142]

The Commerce Department's decision to decontrol Garrett engine technology was considered in the context of several U.S. policies. Two policies in particular dominated the interagency debate: the 1991 Enhanced Proliferation Control Initiative (EPCI), and COCOM controls on jet engine technologies.

Consideration of Enhanced Proliferation Control Initiative Regulations

The Enhanced Proliferation Control Initiative was established by the Bush administration to provide a non-proliferation "safety net." It was intended to restrict the export of technologies usable for chemical and biological weapons or missiles, *regardless* of whether such technologies were controlled under existing international agreements (for example, under the 1987 Missile Technology Control Regime).

As explained by the Commerce Department:

> *Foreign policy controls are being imposed on certain exports by adopting a policy of denial for items that already require a validated license, for any reason other than short supply, where the export is determined to be for a facility involved in* ***the development, production, stockpiling, delivery, or use of chemical or biological weapons or of missiles****.*
>
> *The purpose of these controls is to prevent American contribution to, and thereby* ***distance the United States from****, the proliferation of chemical and biological weapons and* ***missile development.***

These controls serve to demonstrate U.S. opposition to the spread of these weapons and provide specific regulatory authority to control exports from the United States of commodities or technology where there is a significant risk that they will be used for these purposes. [Emphasis added][143]

According to the August 1991 interim Enhanced Proliferation Control Initiative regulations, the Commerce Department should have conducted a "case-by-case" review of Allied Signal's proposed export to determine whether it "would make a material contribution to the proliferation of missiles." If the export were "deemed to make such a contribution, the license [would] be denied."[144]

Baird states that an Enhanced Proliferation Control Initiative review was not conducted for the engines, but was conducted for the production technology: "As far as the engines went, sending the whole engine up, we didn't feel it raised EPCI concerns. As far as the technology went, we did." Baird did not further explain the basis for the Commerce Department decision that the Garrett engines themselves did not require an Enhanced Proliferation Control Initiative review; nor did he explain why the technology did raise EPCI concerns.[145]

The Department of Commerce was unable to provide the Select Committee with any records of the Enhanced Proliferation Control Initiative review it conducted for the Garrett engine production technology.[146]

Allied Signal's partners in the Garrett engine transaction included:

- **The China National Aero-Technology Import-Export Corporation (CATIC)**
- **China Nanchang Aircraft Manufacturing Company**
- **The China National South Aero-Engine and Machinery Company**

A 1992 U.S. Government review of these proposed end users found that the export of Garrett engine production technology to the PRC could pose a national security threat to the United States.

The review found that PRC co-production of Garrett TFE-731-2 engines would enable Beijing to develop higher quality turbojet and turbofan engines for use in military and civilian aircraft and in cruise missiles. PRC access to this production process would also give Beijing the means to extend the range of its cruise missiles. This was of special concern because PLA missiles, rockets, and aircraft are produced at facilities also used for civilian production.

A Garrett representative confirmed that the Zhuzhou South Motive Power and Machinery Complex was the intended producer of the Garrett TFE-731-2 engine. There was concern that a flow-through of applicable production technologies to the PRC's cruise missile engine program was almost inevitable.[147]

The PLA's HY-4 cruise missile is reportedly now powered by a copy of a U.S. turbojet engine.[148] In addition, the conditions placed on the export of the Garrett engine technology of course would not prevent the PRC from reverse engineering the engine if that were the PRC's intent.[149]

Each of the PRC participants in the Garrett engine co-production venture produces military hardware. Despite the assurances of Allied Signal that the engines it proposed to produce in the PRC would be used entirely for commercial purposes, PLA personnel were prominent in the negotiations with Garrett. The CATIC representatives were the same individuals who were prominent in the Committee on Foreign Investment in the United States (CFIUS) case involving the attempted purchase of MAMCO, a Boeing contractor, by CATIC. This is the only CFIUS case in which the President reversed a sale on national security grounds.[150]

Because the PRC could incorporate complete TFE-731-2A-2A engines or modified variants directly into cruise missile airframes, export to the PRC of the engines themselves — as well as the production technology — presented a national security threat.[151]

Consideration of COCOM and Export Administration Regulations

COCOM and Export Administration Regulation reviews were conducted to assess sensitive components in the Garrett TFE-731-2A-2A jet engine.

When Allied Signal's Garrett Engine Division upgraded the TFE-731-2A-2A with the addition of a digital engine controller, it claimed that the new system did not require an export license under the revised Export Administration Regulations and COCOM controls. It was determined that COCOM had not developed an agreed-upon technical definition to distinguish restricted from unrestricted engine controllers.[152] This shortfall in the regime set the stage for an extended interagency debate over the status of the TFE-731-2A-2A vis-à-vis COCOM regulations.

The Defense Department believed the Garrett engines contained an embargoed, full authority digital engine control (FADEC) system. Moreover, the Defense Department obtained new information about improvements to the Garrett TFE-731-2A-2A that raised additional national security concerns.[153]

Regarding the FADEC issue, the Defense Department acquired analysis and technical studies from numerous sources. A Defense Technology Security Administration analysis explained, for example:

> *The Garrett engine contains what [Allied Signal] calls a Digital Electronic Engine Control (DEEC) but describes in company literature as "full-authority, automatic engine control." DTSA maintains that the DEEC is a FADEC for the following reasons:*
>
> *FAA certification officials state in writing that the "DEEC" controller is a FADEC. Also DoD experts at the Air Force Aeronautical Systems Center and the Naval Air Warfare Center have assessed that the Garrett engine controller is a FADEC.*[154]

Additional confirmation of these findings was contained in a technical paper developed by the engineering staff at the Defense Technology Security Administration:

> *In summary, the entire DoD Category 9 [aero-engines] negotiating team to COCOM during 1990-91 . . . are in agreement after detailed analysis, with assistance from experts in controls from Navy, Air Force and FAA, of data proprietary to Allied-Signal and otherwise, that the ASCA [Allied Signal Controls & Accessories division] DEEC, P/N 2118002-202 is a FADEC.*

> *Allied-Signal's memo to DTSA . . . shows this is indeed the FADEC utilized on the GED [Garrett Engine Division] TFE731-2A-2A engine.*

The Defense Department inquiry found further that Allied Signal initially did not provide accurate information to the Federal Aviation Administration during the civil certification process for the TFE-731-2A-2A:

> ***GED [Garrett] was rebuked by FAA engineers*** *in 1988 for their claim that the -2A engine was a direct derivation from a -2 engine rather than being derived from a TFE731-3. GED subsequently provided FAA with a corrected derivation showing that the engine was actually a TFE731-3 with TFE-731-3B parts and components rather than TFE731-2 components.*
>
> *Substantial improvement to the TFE731-2A engine occurred when the so-called "Extended Life Turbine Modifications" were added during December, 1991, only one month after DOC [Commerce] had notified GED it had decontrolled the engine….*
>
> ***The Extended Life Turbine (ELT) resulted from the NASA program to obtain significant reductions in noise and emission levels, i.e., decreased infrared (IR) signature.*** *The ELT has an enhanced damage tolerance and changes TFE731-series engines from an expected life of approximately 6,000 hours to 10,000 hours.*
>
> *In summary, the engine GED [Garrett] submitted for a 'paper certification' as a TFE731-2A in 1988 was not a derivative of a -2 engine but was derived from a TFE731-3 with a TFE731-3B LP compressor. The changes noted above were included in the 1988 engine, i.e., the A5 seal and both LP compressor and turbine blades changed. The ELT was added in 1991.*

> *In conjunction with the slight derating of the engine in 1988, life expectancy of this engine is greatly enhanced over a TFE731-3 turbofan engine; it is more durable, reliable, and generally* ***more appropriate for use on military aircraft.***
>
> ***No applications of this engine to civil airframes are known to have been attempted by Allied-Signal, only military.***[155]
> [Emphasis added]

The evidence obtained by the Defense Department indicated that the TFE-731-2A-2A was not simply a 20-year old engine for business jets, as Allied Signal and Commerce Department officials had claimed.[156] (Indeed, as of January 3, 1999, the TFE-731-2A-2A has never been used in a business jet.)[157]

It is true that the engine had been derived from the TFE-731-3, an engine used in both civil and military applications, including the Cessna Citation III business jet and the CASA C-101BB ground-attack jet. But the engine had been upgraded with a new turbine to lower its infrared signature, thus improving the combat survivability of the aircraft in which it would be contained — for example, through the ability to escape detection by surface-to-air missiles.[158]

Resolution of the Garrett Engine Controversy

The Garrett engine controversy was ultimately resolved through an interagency agreement at the Deputy Assistant Secretary level. Regarding the disputed engine controller, the Deputy Assistant Secretary of Defense for Counterproliferation Policy, Mitchel B. Wallerstein, described an interagency compromise in a March 21, 1994 letter to the Deputy Assistant Secretary for Export Controls at the State Department:

> *Defense is prepared to agree with the Allied (and Commerce) determination that the engine does not include a Full Authority Digital Engine Control System (FADEC) which meets the IVL [Individual Validated License] criteria….With respect to the 2A-2A engine,* ***our proposed carve out from the definition of FADEC would provide a basis for a Commerce G-DEST***

> ***classification which would allow sales of the 2A-2A engine to the PRC, including its military, without prior [U.S. Government] review and approval.*** *It is unclear whether such a definitional carve out would require multilateral coordination with our current allies before such a G-DEST classification is made.*[159]

The State Department agreed with this proposal, and stated further: "We do not believe that it is necessary to coordinate multilaterally with our COCOM partners before moving to G-DEST treatment."[160]

Peter M. Leitner, senior trade advisor at the Defense Technology Security Administration, believes that the "definitional carve out" entailed a political decision to change the definition of the engine controller in order to circumvent export regulations and, in this case, avoid a COCOM review. According to Leitner, "you come up with some unique definition of the item and try to exempt or carve out… coverage of that item in the regulations."[161]

Baird believes that COCOM reviewed the export license application for the upgraded variant of the Garrett TFE-731-2A-2A.[162] Webb believes COCOM did not review the application.[163] The Commerce Department was unable to provide records of any COCOM review conducted for the upgraded Garrett engines.[164]

Defense Department records indicate that some U.S. government officials believed a COCOM review of the upgraded engines was essential. Without such a review, the United States might be seen by its partners as attempting to "circumvent CoCom controls."[165]

Wallerstein interprets the reference to "a carve out from the definition of FADEC" to mean that the disputed FADEC engine controller would be removed or modified to ensure that the TFE-731-2A-2A could be exported without controlled technology.[166] However, Wallerstein does not recall seeing any technical proposal from Allied Signal to modify the engine controller.[167]

The documentary record suggests that the final, upgraded variant of the Garrett TFE-731-2A-2A was never submitted for a review by COCOM, which ceased operations in April 1994.[168]

The status of the Garrett engines vis-à-vis the Enhanced Proliferation Control Initiative was largely resolved on August 19, 1993 during a meeting of the Commerce Department-chaired Operating Committee on Export Policy. According to a record of the meeting:

> *Commerce, State, and Defense have agreed to treat these commodities as if they were controlled. Moreover, [Allied Signal] has agreed not to transfer any co-production technology relating to these engines to the PRC.*[169]

This interagency decision was finalized and reported in the news media in October 1995. As the *Wall Street Journal* reported then:

> *Allied Signal already has shipped about 40 built-up engines to China under the liberalized post-Cold War export rules, and isn't being deterred from exporting 18 more that the Chinese have ordered.*
>
> *But when it sounded out the U.S. Commerce Department last summer about its coproduction plan, the company was told that if it formally applied for a license to do so the application would be denied under the rules of the Enhanced Proliferation Control Initiative … The company decided not to apply for the license.*[170]

Between 1992 and 1996, Allied Signal reportedly exported 59 of these TFE-731-2A-2A jet engines to the PRC. Beijing's main interest was in acquiring a production capability for the engines; thus, it halted further orders when co-production plans were scuttled.[171]

The PRC Continues to Acquire Jet Engine Production Processes

The PRC is continuing its effort to acquire production processes for U.S. jet engines. For example, Pratt & Whitney Canada, a subsidiary of Connecticut-based United Technologies, in February 1996 became "the first foreign company to establish an aviation parts manufacturing joint venture in China (with Chengdu Engine Company)."[172] The Chengdu Engine Company manufactures components for, among other purposes, large jet engines used in Boeing aircraft.[173] The Chengdu factory also manufactures parts for the PRC's WP13 turbojet engine, which powers the PLA's F-8 fighter.[174] In 1997, a new joint venture was reportedly proposed for Chengdu.

> *A consortium of Pratt and Whitney, Northrop Grumman and Hispano-Suiza are offering a new aero-engine, the PW6000, specifically designed to power the AE-100 transport, and are planning to establish an aero-engine joint venture at Chengdu, Sichuan Province.*[175]

United Technologies operates additional aviation joint ventures with Xi'an Airfoil Technology Company and China National South Aero-Engine and Machinery Company. These ventures are largely comprised of manufacturing jet engine "cold section" components or producing relatively low-technology "hot section" components.[176] United Technologies claims that it has coordinated these aviation projects fully with the appropriate export licensing organizations in the U.S. Government.[177]

The PRC may have also benefited from direct exploitation of specially designed U.S. cruise missile engines. According to published reports, the PRC examined a U.S. Tomahawk cruise missile that had been fired at a target in Afghanistan in 1998, but crashed en route in Pakistan.[178]

THE PRC'S ACQUISITION OF MACHINE TOOLS, COMPOSITE MATERIALS, AND COMPUTERS FOR AIRCRAFT AND MISSILE MANUFACTURING

Since the Second World War, the aircraft industry has been among those sectors of the manufacturing industry in the forefront of users of advanced machine tools. Machine tool application in the aircraft industry has been dual-use. The same types of tools and manufacturing processes have been used for both military and civilian aircraft, especially large transport aircraft.

Many of the same machine tools and manufacturing processes are also used in manufacturing strategic and tactical missiles.

The requirements of the aircraft industry, although far outweighed by those of other industries in terms of production volume, have played an important role in helping to motivate the development of machine tools of high precision and versatility. For example, in the United States, some of the earliest research on numerical control of machine tools was sponsored by the U.S. Air Force. The work was done at MIT, with application to aircraft manufacturing as the objective.[179]

The PRC, too, has recognized the importance of machine tools in both its military and civilian aircraft production programs, as well as in industry generally. Particularly since the 1960s, it has embarked on a variety of programs both to acquire machine tools from foreign sources, and to develop an indigenous machine tool industry.

The United States has exported substantial numbers of advanced machine tools to the PRC for aircraft co-production programs, including the Boeing 737 and the McDonnell Douglas MD-80, under end-use agreements and controls. (Prior to the

1960s, before the ideological break with the Soviet Union, the PRC relied to a considerable extent on technology transfer in the aircraft and missile field from the Soviet Union. More recently, since the collapse of the Soviet Union, transfer of aircraft technology from Russia, driven by economics if not ideology, has been increasing.)

Manufacturing Processes for Aircraft Structures

Aircraft structures are constituted mainly of metal parts and subassemblies, employing aluminum alloys, titanium alloys and, to a much lesser extent, steel alloys.

Over the past 30 years, there has been increasing use made of fiber composites of high strength-to-weight ratio, especially in military aircraft; but metal parts remain the predominant structural material for most aircraft, military or civilian.[180]

Metal parts are typically fabricated from sheet, bars (billets), molded pieces (castings), or shaped pieces (forgings). Almost all metal parts require, at some stage of manufacturing, processing to their final dimensions and finish by cutting, metal removal, shaping, or forming. This requires the use of machine tools.

Most of these machine tools are general purpose, and can be used to process a wide variety of parts, as well as to join component parts into subassemblies and assemblies by use of riveting, welding, and bonding. The various types of automatic machinery used in these joining processes may be general purpose, or may be specifically designed or modified for the particular assembly being fabricated.

Machine tools used in aircraft manufacturing today are generally **numerically controlled (NC)**. The more advanced and modern manufacturing facilities are **computer-numerically controlled (CNC)**. Many of today's high-tech machines also have automatic tool changing capability. In factory layouts, these machines are part of *machining centers* where they are integrated with automated systems for materials and workpiece handling (for example, transportable pallets that carry the workpieces).[181]

Another level of automation and process integration that has been achieved in large-scale production only recently (for example, in the Boeing 777) is the integration of computer aided design (CAD) with computer aided manufacturing (CAM).[182] With CAD/CAM, the output of the computer design process is translated directly into numerical computer code that can be sent directly to computer-controlled machines and machining centers.

The next step in manufacturing process integration is **computer integrated manufacturing (CIM)**.[183] In this step, integrated computer controls manage the entire product flow from design to sales to delivery, including not only CAD/CAM but also:

- **Materials ordering**
- **Warehousing**
- **Inventory control**
- **Factory scheduling**

Finally, the integration is being extended to networks of geographically scattered suppliers, creating global infrastructures supporting international manufacturing enterprises.[184]

High-Tech Metal Cutting

To a considerable degree, the extent of advanced capability of computer-numerically controlled machine tools is indicated by the number of axes that can be controlled. (This is often how the sophistication of these machines is described in export control documents.)

The "number of axes" means the number of motions of either the tool or the workpiece that can be simultaniously controlled.[185] Thus, a drilling machine in which the tool can travel vertically, and the workpiece is held to a bed that can travel both horizontally and laterally, is a three-axis machine. Three-axis machines are widely used, and widely available worldwide.

A milling machine is one of the most versatile machine tools. And when a milling machine's cutter is fixed, and the workpiece is mounted on a pallet that can not only move vertically, horizontally, and laterally, but also rotate about two perpendicular axes, it becomes a five-axis milling machine. There are other combinations of tool and pallet motions that may be advantageously embodied in five-axis milling machines, depending on the particular applications of those machines.

There is no fundamental difficulty in conceiving or understanding the design and operation of these sorts of five-axis machines. It is believed that some five-axis machines may have been manufactured in the PRC.[186] However, the design and production of five-axis milling machines capable of maintaining the highest levels of accuracy and control of workpiece tolerances — during high-speed machining, over the entire range of three-dimensional motions and rotations that the machine may trace out in machining a complex part — calls for a high degree of capability in machine tool and supporting technologies (for example, materials and quality control).

It is not believed that the PRC has yet attained that level of capability. But such sophisticated five-axis machines have been exported from the United States to the PRC under license, with end-use controls, for use in co-production of commercial aircraft. In addition, the PRC may have been able to import them from one of the several non-U.S. countries that manufacture them.

The value of high precision multiple-axis machines in manufacturing is that they broaden the range of design solutions available for structural elements and for structural assemblies. In most cases, an aircraft structural designer (or computer design program) without such advanced machine capabilities would have to design less optimal parts and structures. This would mean disadvantages in terms of the extra weight of the parts and structures, and a higher unit cost relative to what could be achieved with more advanced machine tools.

However, in some instances, increased effort by highly skilled craftsmen can offset the disadvantages of using less advanced or lower-precision machine tools. In advanced industrial economies such as the United States, the high cost of such skilled labor almost always strongly favors investments in more advanced machinery. In the PRC, the cost tradeoffs in favor of advanced machinery over additional skilled labor are less.

Nevertheless, for the PRC, the advantages of having advanced machinery for manufacturing both modern civilian transport and military aircraft remain sufficient to motivate continuing efforts on their part to acquire them. In co-production arrangements with the major aircraft producers, it is usually necessary for the PRC to be provided with the same types of machines with which the parts being co-produced were originally designed.

The progress in refinement of machine tools has been substantial in recent years. For the most part, this progress is the result of advances in control systems, and in the machines' associated software. The mechanical components of machine tools have remained mostly unchanged over the past decade, although there have been a few improvements, such as higher spindle speeds. The more modest advances in the mechanical precision and versatility of machine tool control have complemented the rapid advances in computer-aided design and manufacturing. In part, the improved mechanical components themselves are the result of these vastly improved CAD/CAM capabilities; the improved machine tool components also make it possible to use CAD/CAM capabilities more effectively.

The following table indicates the improvements in the accuracy and repeatability of five-axis machines over the past decade.

Recent High-Tech Improvements in the Accuracy and Repeatability for 5 Axis Machines

	1988	1998
Linear Accuracy	0.0005 – 0.0010 inches	0.0001 – 0.0002 inches
Repeatability	50 millionths of an inch	5 to 10 millionths of an inch
Rotary Accuracy	0.01 to 0.001 degrees	Better than 0.001 degrees

Thus, 10-year-old machines are well below current best levels of accuracy.

The current thresholds for subjecting metal cutting machines to export controls are, for example, positioning accuracy of 4 to 6 microns (around 0.00012 inches) and rotary accuracy, when specified, of 0.003 degrees. Milling machines with five or more axes are subject to export controls regardless of accuracy.

In the advanced industrialized nations, machine tool accuracy has increased across the entire spectrum of computer-numerically controlled machine tools. For example, the latest grinding machine tools for use in high-volume production can produce concentric circles accurate to within five ten-thousandths of an inch. These same machines can guarantee flatness to within 50 millionths of an inch. They can bore holes with dimensions accurate to within four ten-thousandths of an inch, and then repeat the process endlessly with a variation of no more than 0.0002 inches. Today's specialty machines have even better accuracy and repeatability figures.

Metal Forming for Aircraft Manufacture

Sheet metal forming operations are important in aircraft manufacture. For example, the process known as **"stretch forming"** — in which a metal sheet is held at its edges, and stretched over a form or die that can be moved — is used to manufacture large sections of skin (up to 40 feet long) for the Boeing 757 and 767.[187]

Visitors to PRC aircraft manufacturing plants several years ago noted that there seemed to be only a limited capability for stretch forming, especially for larger, heavier workpieces.[188]

There are many variations of metal forming operations. In **"stretch-draw forming,"** a metal sheet is gripped in tension, and then pressed by upper and lower mating dies using hydraulic force.[189] Other types include:

- **Press brake bending**
- **Spinning**
- **Deep drawing**
- **Rubber forming,** in which the metal sheet is forced into a rubber medium on one side by a die on the opposite side[190]
- **Hydraulic stretch forming presses,** used to form extruded parts to shape
- **Hot forming**, of special importance in manufacturing titanium aerospace parts

One modern type of forming operation is known as superplastic forming,[191] because it takes place at a temperature above which some metals become plastic. The titanium alloy Ti-6AL-4V, which is widely used in aircraft parts, can be formed this way using a variety of forming techniques.

A more complex application of superplastic forming is done in combination with **diffusion bonding**.[192] In this process, two sheets are diffusion bonded at designated areas under high temperature. The unbonded areas of one of the sheets then undergoes superplastic forming into a die, forced by argon gas pressure. These techniques have been extended not only to titanium alloys, but to some aluminum alloys as well.

Superplasticity and diffusion bonding technologies for alloys of titanium, aluminum, and certain other metals are subject to export controls.

Non-Mechanical Manufacturing Processes

There are a number of manufacturing process to remove, shape, and finish structural and component parts that do not rely on cutting with solid tools. Instead, these processes use chemical, electrical, thermal, and other methods to cut, shape, and finish metals and other materials.

Of these methods, **chemical milling**[193] is the most widely used on metal aircraft and missile parts. In chemical milling, a mask is placed over areas of a metallic workpiece where metal is *not* to be removed. The metal workpiece is then placed in a chemical bath that etches metal away from the unmasked areas. This process is not subject to export controls, and is well within PRC capabilities.

Electrochemical machining[194] employs a negatively-charged, shaped electrode to remove material from a positively-charged metal workpiece in a conductive chemical fluid (electrolyte). This process is more complex than chemical milling, and can be used to produce complex shapes with deep cavities.

Electric discharge machining (EDM) removes electrically conductive material by means of controlled, repeated electric discharges.[195] The chips are removed by flushing with a dielectric fluid. When EDM is used for grinding, the workpiece is fed into a negatively-charged rotating wheel. This type of EDM is not subject to export controls. In another form of EDM, a moving wire is brought to within arcing distance of the metal part being cut in a dielectric fluid. This type of EDM is subject to export controls. Both types of EDM are on the U.S. Militarily Critical Control Technologies List (MCTL) if the number of rotary axes for contour control exceeds five (for the wire type), or two (for the nonwire type).

Laser beams are also used for cutting metals and other materials.[196] Either solid-state lasers or gas lasers may be used for this purpose, including:

- **CO2 lasers**
- **Ruby lasers**
- **Neodymium lasers**
- **Neodymium-YAG lasers**

Export controls apply to laser tools, and these tools are listed in the Missile Control Technology List (MCTL) if they have two or more rotary axes that can be coordinated simutaneously and have positioning accuracy better than 0.003 degrees. However, lasers of the types and power levels useful in most material machining applications are widely available worldwide, and to the PRC.

High velocity water jets generated by pressures of 60,000 pounds per square inch and above are also used for cutting materials, especially plastics and composites.[197] A related process is **abrasive water-jet machining**, in which abrasive particles such as silicon carbide are added to the water to increase the material removal rate.

Export controls apply to water-jet machine tools, and are noted in the MCTL if they have two or more rotary axes that can be coordinated simultaneously and have a positioning accuracy of better than 0.003 degrees.

The Use of Computers for Machine Control

Much of the recent improvement in machine tool capabilities is attributable to advances in the use of computers for machine control. Moreover, further advances in machine control technology are in the offing.

Although there is some uncertainty as to the level of PRC technology in this area, there has been no credible evidence that it is up to the state of the art of the highly-developed nations (the United States, Japan, and Western Europe).

The PRC's inability to achieve state-of-the-art in computer-control system technology for machine tools is not due to a lack of theoretical knowledge. PRC engineers regularly attend, and present papers at, meetings dealing with most of the frontier developments in machine tools and their control systems.[198]

Rather, the PRC has been inhibited by shortcomings in its industrial infrastructure. The PRC also lacks the ability to integrate the contributions of the many disciplines that are required to utilize the rapidly emerging new technologies. The PRC system is unable to keep up with these basically new approaches.

Control system technology for machine tools is rapidly starting to change. Among the most important changes on the horizon is the emergence of "open architecture" control systems. These systems use personal computers for machine control.

While PCs of sufficient capability for the control of sophisticated machine tools are now available in the PRC, and it is believed that motion-control boards needed for this purpose are also generally available, software for machine control is the other necessary element. The PRC would need specialized software to achieve a highly capable machine tool control system. At present, export controls are imposed on software for machine tool control that can be used to contour control independently and simultaneously on more than four axes.

In addition, there are controls on software that can adaptively use the measurement of at least one physical variable through a computational model to change one or more machining instructions.

Capabilities to produce software for PCs are widely diffused throughout the world, and are growing steadily in the PRC itself. As a result, these controls on software may not be as effective in the future, as these new trends in machine tool control develop.

An important aspect of advanced software for machine tools is that it can be used to compensate for a machine tool's mechanical errors, if the errors are repeated. This is done by mapping the machine's performance against a known standard, and then compensating for positioning errors.

As machine control systems move increasingly toward becoming PC-based, these "open architecture" systems will make error correction systems easier to implement, and more widely used.

Fiber Composite Materials and Structures

Since the early 1970s, there has been a trend toward replacing metals with fiber composites in the primary structure of aircraft.[199]

The main reason for the adoption of fiber composite materials and structures is that they weigh less than metals, but provide the same or better stiffness and strength. In addition, composite materials and structures usually last longer (that is, they have a greater time-to-failure under repeated or cyclic loading) than metal parts designed for the same maximum static loads. They also vibrate less.[200]

A disadvantage of composite materials and structures is that the manufacturing processes to use them are more complicated, and consequently they add costs. They also require more advanced nondestructive evaluation techniques for quality control and field maintenance. In light of these factors, the trend toward replacing metals with composites has thus far proceeded much more rapidly in military aircraft than in civil aircraft.

For helicopters and other vertical take-off and landing aircraft,[201] however, the trend toward fiber composites began earlier and proceeded faster. Initially, fiberglass composites were the material of choice, even though they have much lower strength and stiffness properties than the boron and carbon/graphite composites that were later utilized in fixed-wing aircraft. The reason that fiberglass composites were attractive for helicopters (and other vertical take-off and landing aircraft) is that structural weight savings on these aircraft have a relatively higher payoff in performance than on fixed-wing, horizontal take-off aircraft. Moreover, the load intensities on a helicopter's non-rotating parts tend to be lower than on high-speed fixed wing aircraft.

Among the advantages of composite structures is that a structural part can be designed to have different strength properties in different directions. That is, it can be stiffer in one direction, and more flexible in another. This permits it to be tailored to the loading conditions of specific applications.

For this reason, fiber composite structures are especially well adapted to the application of radar signature reduction techniques. It should be noted that the use of composites in and of itself is not enough to give an aircraft stealth properties; a fiber composite structure aircraft without radar signature reduction features will not necessarily have a lower radar cross-section than a metal structure.[202] The subject of stealth in relation to composite construction is discussed more fully under the heading *"Stealth and Composite Techniques,"* later in this *Technical Afterword*.

Although fiberglass composite materials have been used in aircraft manufacturing since the early 1950s, most of the applications of this material originally were for secondary structure not considered critical for flight safety. (A notable exception was the use of fiberglass/epoxy resin composites for helicopter rotor blades — experimentally in the 1950s, and then in production in the late 1970s.) Fiberglass/epoxy resin composites using S-glass, although of high strength and stiffness relative to most homogeneous plastics, did not begin to approach the strength and stiffness of aluminum alloys, much less those of high-strength steel alloys. But they could be used in secondary structures for their weight and sometimes manufacturing cost advantages relative to alternatives.

A turning point in the application of fiber composites to aircraft, rockets, and ballistic missiles took place in the early 1960s, with the discovery and development of the high strength and stiffness properties of boron fibers. Single boron fibers in tension (that is, subjected to stress in one direction) were found to be stronger and stiffer than the best available high-strength steel alloys.

The use of a boron/epoxy resin composite then followed. It can be used for aircraft, rocket, and ballistic missile structural elements that are designed to take multidirectional loads, such as are typically encountered in aircraft primary structures. Boron-epoxy resin composites are formed and cured in autoclaves (essentially, pressure cookers) under controlled high temperatures and pressures, in much the same way as the earlier fiberglass/epoxy resin composites were made. Boron-epoxy resin composites are just as strong and stiff as aluminum and steel alloy structures, if not better, and weigh less.

Very shortly after the introduction of boron fibers, carbon/graphite and Kevlar fibers were introduced. Depending on the particular application and type of loading, these offered material properties and unit weights comparable to boron fibers, and at lower cost.[203]

It required some years of development, including ground and flight testing of experimental structural components, before boron/epoxy resin composites were first used in the primary structures of production aircraft. Their first use was in the horizontal tail surfaces of the Navy F-14A aircraft, in the early 1970s. This was followed shortly by the F-15A, which used boron/epoxy composites for both its horizontal and vertical tail surface structures.

Since then, there has been a steadily increasing trend toward the use of the various high-strength, high-stiffness fiber composites, particularly graphite/epoxy, in primary structures in military aircraft. The same trend is underway, albeit at a slower rate, in civilian aircraft.

The progression in composite usage in primary structures has been as follows:[204] [205]

High-Tech Fiber Composites in Military and Civil Aircraft

Military Aircraft	Percentage of Primary Structure	Civil Aircraft	Percentage of Primary Structure
F-15A	4-5%	**Boeing 767**	3-4%
F-16	12%	**Airbus A300-600**	4%
FA-18E/F	19%	**Airbus A310-300**	8%
AV-8B	26%	**MD-11**	5%
F-22	35%	**Boeing 777**	9%
		Airbus A-340	12%

Composite Structure Fabrication Technologies

The manufacture of fiber composite structures generally begins by combining the fiber with epoxy resin, or some other so-called "matrix" material. The resulting prefabricated sheets are called *prepreg*. Successive layers of these *prepreg* sheets are then placed in a mold that is shaped to the form of the part being fabricated.

The fiber directions in successive prepreg layers are diagonal to one another, in a fashion tailored to the load and stress field to which the part will be subjected. The stack of prefabricated sheets — called a "layup" — is then cured in an autoclave (essentially, a pressure cooker) under controlled high temperature and pressure.

Initially, the task of making the layups in molds was done by hand. Later, beginning with simple, near two-dimensional parts, computer-controlled automated layup machines became available. Today, automated layup machines are capable of handling ever more complex parts.

Attachments between fiber composite structural elements have, for the most part, been made with bolts. In some cases, adhesive bonds have been used, in much the same manner as with metal parts. More recently, the layups for two or more parts have been joined in the curing process — this is called *cocuring*.

These fiber composite fabrication processes permit the manufacture of parts in nearly final form ("near net shape"). However, some cutting, drilling, and other machining and finishing operations are usually required.

Much of this is done with conventional machine tools. But the tool shape and hardness, and the cutting speeds, must be adapted to the fiber composite material being worked. Laser cutting and water jet/hydroabrasive cutting are also used extensively in finishing operations for fiber composites.

For axially-symmetrical parts — such as rocket motor cases — filament winding is used (for example, in the Minuteman missile's upper stage). Filament winding has also been used to manufacture fiberglass/epoxy helicopter rotor blades. In addition, long parts of constant cross-section can be made by the **pultru-**

sion process: pulling the fibers and matrix material through a die. This is the analogue of the extrusion process for metals.

Most of the fiber composite structures produced to date have employed polymer matrix materials that cannot be subjected to severe temperature environments. This has been a strict limitation on the kinds of structures for which fiber composites can be used. But newly-developed composite materials do not have this limitation. These new materials include:

- **Metal matrix composites**
- **Ceramic matrix composites**
- **Carbon/carbon composites**

These new fiber composites can be used in higher-temperature applications such as rocket engines, hypersonic aircraft, and ballistic missiles.[206] [207]

The PRC has been seeking to acquire or develop composite materials and structures technologies. One route has been through seeking co-production relationships for subassemblies of commercial aircraft and helicopters that have significant composite parts.[208] There are also reports of indigenous development as well.

A wide range of composite materials and structures fabrication equipment is included in the Missile Control Technology List (MCTL), and is subject to export control regimes at some threshold of capability. These include:

- **Composite filament winding**
- **Tape laying**
- **Weaving**
- **Prepreg**
- **Fiber production equipment**

The more advanced Western methods of composite structure fabrication for complex three-dimensional shapes are extremely sophisticated robotic machines — some with as many as nine axes of motion. It is not believed that the PRC has been able to develop or acquire machines of this capability as yet.

Stealth and Composite Technologies

What is stealth? Simply put, stealth is the ability to conceal an attacker from a defender's detection and defensive systems, and successfully accomplish the mission.[209] Stealth does not make the attacker invisible, only more difficult to detect.[210] To avoid detection, it is necessary to reduce or eliminate the attacker's "signature."

The "signature" is composed of five primary elements:

- **Visual signature**
- **Infrared (heat) signature**
- **Acoustic (noise) signature**
- **Radio transmission signature**
- **Radar signature**[211]

The first three signatures are relatively short range.[212] The radar signature is the most important, because it can be detected at the longest range — up to 400 miles away.[213]

In a stealth vehicle, attention is paid to all five signature sources.[214] To reduce the infrared and acoustic signatures of an aircraft, the engines are buried inside the fuselage or wings. Special non-reflective paints and paint schemes reduce the visual signature. The radio transmission signature can be reduced or eliminated by secure communications or radio silence.

Defeating radar detection is relatively simple in principle.[215] It involves designing the vehicle so that the incoming radar signal is reflected away from the defender's radar receiver, or absorbed by the vehicle itself using radar-absorbing materials.[216] Radar stealth is accomplished in five ways:

- **Designing the vehicle so that there are no surfaces pointing directly back to the source radar**
- **Using radar-absorbing materials on surfaces that could reflect back to the source radar**

- **Removing surface roughness by making the surface of the vehicle as smooth as possible**
- **Designing engine inlets to reduce reflection**
- **Burying engines and weapons inside the vehicle**[217]

The F-117 and B-2 aircraft represent the cutting edge in manned stealth aircraft, because they combine all of the elements of design, materials, and manufacturing technology to achieve stealth, including radar and infrared invisibility.[218]

Why is stealth so important to the military? Stealth vehicles are difficult to counter by a defender.[219] In military terms, stealth insures a greater probability of completing a mission and increased survivability of U. S. forces.[220] Other benefits include:

- **The ability to range over a greater area of enemy territory without being detected**
- **Reduced mission cost**
- **Increased effectiveness of other radar-jamming systems, such as chaff**[221]

The PRC probably cannot build stealth aircraft or missiles with the same capabilities as the F-117 and B-2, now or in the near future. But the PRC is likely to try to acquire most of the key elements necessary to build them.

Even acquisition of these elements will be insufficient to permit the PRC to build effectively stealthy aircraft or missiles. System integration of stealth is a major additional task facing the PRC.

The PRC's Acquisition of Stealth Design Technology

The PRC's efforts to solve the stealth design problem received a major boost when the PRC was able to import both high performance computers, and software packages known generically as "finite element" software. This software is used to assess aerodynamic forces and stresses on three-dimensional structures.

"Finite element" software also has the capacity to solve complex sets of Maxwell's equations. These equations relate to electromagnetic radiation (that is, radar) around a structure.

With high performance computers and "finite element" software, the PRC now has the capability to design aircraft which are aerodynamically feasible and then evaluate their stealth capabilities, too.

The Department of Defense has sought tighter export controls on "finite element" software.[222] This software is distinctly dual-use, with civilian applications including automobiles, off-shore oil drilling platforms, and the design of nuclear reactor plants. One of the main concerns of the Defense Department, however, is its use in stealth applications. The software is also critical for anti-submarine warfare.[223]

The PRC's Acquisition Of Composite Materials Technology

Building composite structures for aircraft is, in some ways, similar to building a fiberglass boat: the rigid fiberglass is technically a composite material, made up of layers of fiberglass fabric and epoxy resin. In composite structures for aircraft, the fabric is woven from ceramic, polymer, or carbon/carbon materials, instead of fiberglass.[224]

Large rolls of the fabric are run through machines that apply a coating of uncured resin to the fabric (known as *prepreging* the fabric). This material bonds together, forming the composite structure.

In stealth aircraft structures, radar-absorbing layers and coatings are integrated into the composite structure.

Some PRC joint ventures are adding to the PRC's ability to produce composite airframes:

- **British Petroleum America proposed to sell to the PRC proprietary technology for resins and reinforcing materials,** as well as the technology and training to operate a facility.[225] The company also planned to sell the methodology for translating manufacturing requirements into optimized semi-finished materials. BP America specifically sold the PRC technical data for hot-melt prepreg formulations,[226] and for an acrylonitrile plant.[227] The prepreg technical data was sold to the AVIC China Helicopter Corporation.[228]

- **Hexcel was willing to supply the PRC with high-temperature curing resins and the production equipment and training** to apply the resin to fabric materials.[229] Specifically, Hexcel planned to give the PRC the technology for 250 F and 350 F epoxies.[230] The company planned to transfer to the joint venture a solution-impregnation coating tower for fabrics, and hot-melt impregnating equipment for tapes.[231] The joint venture was supported by exports of carbon epoxy prepreg to the Chengdu Aircraft Industry Corporation[232] and the Xian Aircraft Company.[233] In addition, Hexcel was going to transfer Boeing Aircraft Company's specifications for advanced composites,[234] graphite,[235] Kevlar,[236] and conductive fabrics.[237]

Kevlar is used to make high-strength smooth surfaces on stealth aircraft. The graphite and conductive fabrics are used for radar-absorbent surfaces of stealth aircraft. In addition to their uses for stealth technology, the growing importance of composite structures in all aircraft construction provides an incentive to the PRC to acquire this technology even for non-stealth aircraft — military and civilian.

The PRC's Acquisition of Composite Structures Manufacturing Technology

Obtaining the design capability and the materials-production capability were still not sufficient for the PRC to build aircraft with composite structures. The missing element of the Chinese puzzle was the ability to manufacture aircraft parts with consistent performance time after time.

The answer to this question was found in a joint venture with the Sikorsky Aircraft Company.[238]

The Sikorsky Aircraft Company joint venture with the PRC proposed to build the composite tail section of the civil S-92 helicopter.[239] Sikorsky would teach the PRC to design and fabricate the tail section using proprietary technology to meet Federal Aviation Agency standards of quality and performance.

The project included teaching the PRC to fabricate aircraft components using carbon fiber materials (which are also used in stealth aircraft).[240] In addition to showing the PRC how to use the materials, Sikorsky also taught the PRC about:

- **Bag molding**
- **Mold releases**
- **Die manufacturing**[241]

The key requirements the PRC expected to obtain from the venture were precision tooling, repeatability, and a high production rate.[242]

Overall Assessment

The PRC acquisition of composite technology is an interesting case study. It indicates a broad-based set of joint-venture initiatives directed toward providing for the PRC a state-of-the-art composite materials/aerospace structure capability.