






CHINA'S IMPACT ON METALS PRICES IN DEFENSE AEROSPACE




DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DECEMBER 2005

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This report was produced by the Office of the Deputy Under Secretary of Defense (Industrial Policy). Jody Tran-Le and Stephen Thompson led this effort. Ronald Genemans, Elizabeth Davis, David Chu, and Dawn Vehmeier also had major roles in the production of this report. The team would like to acknowledge the contributions of the companies, organizations, and associations who provided data on a compressed timeframe. Inquiries regarding the report should be directed to Jody Tran-Le at (703) 607-4064.

CHINA'S IMPACT ON METALS PRICES IN DEFENSE AEROSPACE

OFFICE OF THE DEPUTY UNDER SECRETARY OF DEFENSE
(INDUSTRIAL POLICY)

DECEMBER 2005

CHINA'S IMPACT ON METALS PRICES IN DEFENSE AEROSPACE

Assess effects of increased demand for metals and commodities.
Collect and validate industry data.
Access financial community and industry association estimates of long term price developments for major metals of interest to the Department.
Assess the impact of Chinese demand on the metals of interest.
Assess the impact of future prices on a representative sample of fixed-wing production aircraft program costs.

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EXECUTIVE SUMMARY

The prices of steel, aluminum, and titanium have risen considerably over the last two years. Lead times of these materials also have increased. Some believe that significantly increased Chinese demand is responsible for these trends while others are of the opinion that the increases are caused by economic trends associated with widening industrial globalization. Aerospace grade steel, aluminum, and titanium offer unique performance characteristics required by myriad Department of Defense (DoD) weapon systems and not available in other materials. As these metals are of critical importance for a variety of DoD applications, the Office of the Deputy Under Secretary of Defense for Industrial Policy (ODUSD(IP)) initiated this study to assess the impact of rising prices and demand for militarily-critical metals and the associated cost implications to defense weapon system acquisitions.

This study assesses the effects of globalization on key metals demand and the role China plays in that demand. It models and assesses price trends for major materials of interest to the Department and the impact those price trends may have on defense acquisitions.

This assessment focuses on a representative sample of fixed-wing military aircraft that are in production, or soon will enter production (C-17, F/A-18E/F/G, F-22A, and F-35 (JSF)). These aircraft not only represent a major portion of the DoD acquisition budget, they also utilize these three metals in large quantities.

Although the Department uses large amounts of steel, aluminum, and titanium, it is a relatively small consumer when compared to total U.S. production of metals, particularly for steel and aluminum. The Department consumes about 0.3 percent of U.S. steel production, three percent of aluminum production, and 16 percent of titanium production.[1] DoD weapons systems primarily use specialty metals which are produced by the same U.S. suppliers that produce metals for the commercial markets. Although the Department is a small consumer of commercial grade metals, tight commercial markets could negatively impact the viability of U.S. metals suppliers, and ultimately the cost of DoD weapon system programs.

Factors such as world economic recovery and the commercial aerospace rebound have influenced metals prices. However, current Chinese demand is among the major factors in the rising global demand for steel and aluminum. On the other hand, Chinese demand has a limited impact on the rising global demand for the price of titanium.

China is experiencing rising average incomes, rapid urbanization, growing entrepreneurship, and an economy increasingly open to trade. These factors are

[1] Defense Federal Acquisition Regulations Supplement (DFARS) 252.225-7014 generally requires any specialty metals (including titanium and certain steel alloys) incorporated in articles delivered under DoD contracts to be melted in the United States.

dramatically increasing Chinese demand for buildings, cars, appliances, consumer goods, and improvements to transport and communication systems, all of which are dependent on metals. Construction is the largest single factor affecting steel and aluminum demand in China.

Due to its rapid development, industrialization, and extraordinary growth over the last several years, China today is the world's largest consumer of both steel (39 percent of world consumption) and aluminum (30 percent of world consumption). Direct Chinese demand for titanium in the world market is small (five percent) but growing. Securing access to the major metals needed to modernize the Chinese economy is an important element in China's overall comprehensive national resource strategy. Indirectly, Chinese marine, airplane, and industrial power generation purchases also are adding to worldwide demand for titanium.

Global steel and aluminum markets are adjusting to increased demand by expanding capacity. Generally, worldwide steel and aluminum production capacity is expected to outpace worldwide demand. The result will be stabilized or declining steel and aluminum prices. Much of the new capacity is being put into place in China. Today, China is the world's largest producer of both steel and aluminum. In fact, China is already a net exporter of aluminum and is becoming a net exporter of steel. As worldwide steel and aluminum production capacity begins to exceed demand, China may have an incentive to maintain its domestic production by reducing its prices, putting pressure on other steel and aluminum producers—including U.S. steel and aluminum producers.

Global titanium demand also is increasing. However, there is limited information available on projected worldwide titanium production or production capacity. It is not clear whether titanium prices are likely to increase, stabilize, or decline.

Specialty metals as a percentage of the unit recurring flyaway cost represent a small portion of military aircraft prices. Although additional steel and aluminum price increases appear unlikely, the potential for future titanium price increases remains. Significant future titanium price increases could lead to aircraft price increases for which the Department would have to plan. For example, a 50 percent titanium price increase would increase the unit price of an F-22A by $1,274,000 and the FY05-11 buy (104 aircraft) by $132,454,000. Long-term agreements between prime contractors and metal suppliers could substantially mitigate the impact of unexpected price increases.

The chart on the following page summarizes the results of a sensitivity analysis examining various potential metals price increases. This report forecasts that aluminum and steel prices will not increase significantly in the future. However, if aluminum prices were to increase by 25 percent, the largest unit price increase would be $1,455,000 for the C-17 and result in a total increase buy cost of $61,091,000 over 42 aircraft. If steel prices were to increase by 25 percent, the largest unit price increase would be $65,000 for the C-17 and result in a total increase buy cost of $2,737,000 over 42 aircraft. Titanium price increases may be more likely. A 25 percent titanium price increase for the F-22A would increase unit price by $637,000 and the total buy by $66,227,000 over 104 aircraft.

POTENTIAL NET INCREASES IN AIRCRAFT COSTS (THOUSANDS OF FY05 $)

Aircraft Type	Steel				Aluminum				Titanium			
	Base	*10% increase*	*25% increase*	*50% increase*	*Base*	*10% increase*	*25% increase*	*50% increase*	*Base*	*10% increase*	*25% increase*	*50% increase*
C-17												
Base	261				5,818				1,056			
Increase/Unit		26	65	130		582	1,455	2,909		106	264	528
Increase/Buy 2005-2011 (42 aircraft)		1,095	2,737	5,474		24,436	61,091	122,182		4,435	11,089	22,177
F/A-18E/F												
Base	27				302				183			
Increase/Unit		3	7	13		30	75	151		18	46	92
Increase/Buy 2005-2011 (190 aircraft)		511	1,278	2,556		5,735	14,339	28,677		3,483	8,707	17,414
F/A-18G												
Base	28				318				193			
Increase/Unit		3	7	14		32	79	159		19	48	96
Increase/Buy 2005-2011 (90 aircraft)		255	637	1,274		2,860	7,149	14,298		1,736	4,340	8,681
F-22A												
Base	140				521				2,547			
Increase/Unit		14	35	70		52	130	260		255	637	1,274
Increase/Buy 2005-2011 (104 aircraft)		1,461	3,651	7,303		5,414	13,536	27,072		26,491	66,227	132,454
F-35 (CTOL)												
Base	3				238				162			
Increase/Unit		0.3	1	2		24	60	119		16	40	81
Increase/Buy 2005-2011 (79 aircraft)		27	68	135		1,881	4,703	9,405		1,279	3,198	6,395
F-35 (CV/VSTOVL)												
Base	5				245				233			
Increase/Unit		0.5	1	2		24	61	122		23	58	116
Increase/Buy 2005-2011 (111 aircraft)		52	129	259		2,719	6,796	13,593		2,583	6,456	12,913

Sources: OUSD(AT&L)/Defense Systems and Industrial Policy

Global economic conditions including the effect of rising economies such as China's and India's will be significant factors in the supply, demand, and prices for many commodities. All consumers, including the Department of Defense, will be impacted by these global conditions. Considerations of particular importance for the Department include:

- The Department's smaller share of the market for raw materials lessens its ability to influence the market. Industrial policy levers that attempt to influence supply and demand for defense products are less likely to succeed where the defense demand is a very small percentage of the overall market.
- In a global marketplace it is more difficult to separate defense and commercial needs and trends.

ODUSD(IP) will continue to monitor global economic trends that may impact the Department of Defense.

PART I

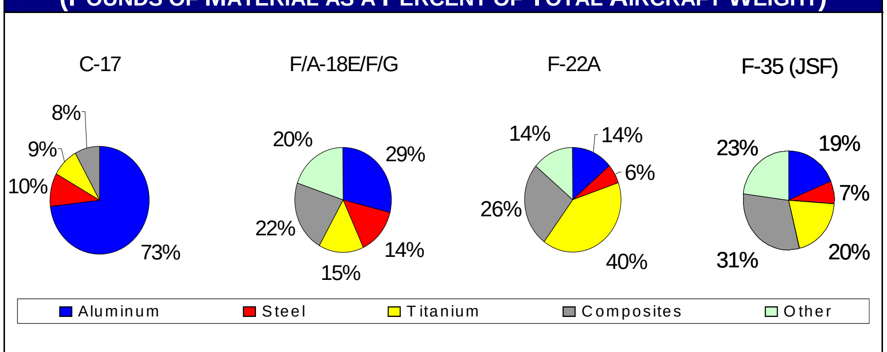
RECENT METALS TRENDS

The prices of steel, aluminum, and titanium have risen considerably over the last two years. Lead times of these materials also have increased. Some believe that significantly increased Chinese demand is responsible for these trends while others are of the opinion that the increases are caused by economic trends associated with widening industrial globalization. Aerospace grade steel, aluminum, and titanium offer unique performance characteristics required by myriad Department of Defense (DoD) weapon systems and not available in other materials. As these metals are of critical importance for a variety of DoD applications, the Office of the Deputy Under Secretary of Defense for Industrial Policy (ODUSD(IP)) initiated this study to assess the impact of rising prices and demand for militarily-critical metals and the associated cost implications to defense weapon system acquisitions.

This study assesses the effects of globalization on key metals demand and the role China plays in that demand. It lays a foundation for modeling and assessing price trends for major materials of interest to the Department and the impact those price trends may have on defense acquisitions.

It is impractical to assess these materials within every sector of the defense industrial base. This assessment focuses on a representative sample of fixed-wing military aircraft that are in production, or soon will enter production (C-17, F/A-18E/F/G, F-22A, and F-35 (JSF)). These aircraft not only represent a major portion of the DoD acquisition budget, but also utilize all three of these metals in large quantities, as shown in the graphic opposite.

MILITARY AIRCRAFT SPECIALTY METALS CONTENT[2]
(POUNDS OF MATERIAL AS A PERCENT OF TOTAL AIRCRAFT WEIGHT)



Sources: Lockheed Martin Aeronautics Company and The Boeing Company

Although the Department uses large amounts of steel, aluminum, and titanium, it is a relatively small consumer when compared to total U.S. production of metals, particularly

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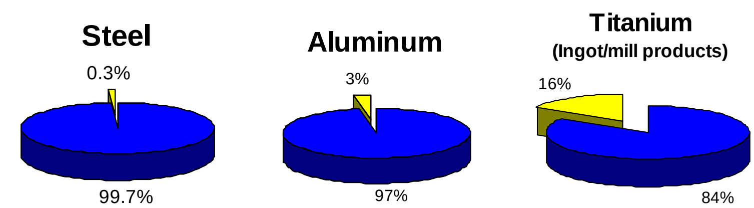
[2] The amount of metals to be procured for the production of an aircraft (Material Buy Weight) is significantly greater than the actual amount of that same metal present in the aircraft (Material Fly Weight). To achieve high strength, with minimal weight, designers often choose metal plates and forgings for structural components. Forgings and mill suppliers generally ship components in rough finished forms due to limitations in providing near-net shapes. Instead, parts undergo finish machining to gain the proper dimensional tolerances and to meet weight requirements for the airframe. As a result, 80-95 percent of the metal may be machined from the rough forging and end up as scrap.

for steel and aluminum (0.3 percent, three percent, and 16 percent of annual U.S. steel, aluminum, and titanium production, respectively, as shown below).

DOD CONSUMPTION
(PERCENT OF TOTAL U.S. PRODUCTION)



Sources: Steel – *Investigation Conducted Under Section 232 of the Trade Expansion Act, Study of Iron-Ore and Semi-Finished Steel,* Department of Commerce, October 2001, based on data from the American Iron and Steel Institute (percentage based on weight).

Aluminum – Department of Commerce (Office of Materials and Machinery).

Titanium – *Titanium Industrial Base Assessment,* Defense Contract Management Agency/ Industrial Analysis Center, June 2003.

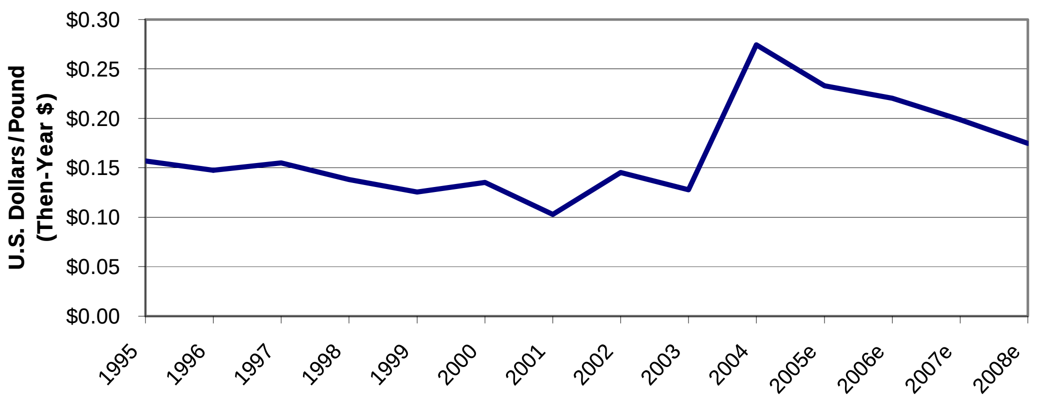
PRICE TRENDS

In 2003 and 2004, prices for steel, aluminum, and titanium rose considerably.. Significant price increases, if not properly planned for within program contracts for DoD weapon systems, could generate cost instabilities. The following paragraphs summarize the status of each of the material markets of interest and the associated economic dynamics that influence materials prices.

STEEL

Investment analyst firm SG Cowen projects, as shown in the graphic on the next page, starting in 2003, and continuing in 2004, prices for U.S. hot-rolled steel sheet increased dramatically. As will be demonstrated later, world economic recovery, combined with especially rapid demand growth in China, attributable in large part to expanding infrastructure and transportation sectors, drove up world demand for steel, tightened supplies, and pushed up prices. However, prices peaked in the second half of 2004 and began to decline as new capacity came online faster than demand growth, putting downward pressure on prices. As of December 2005, prices continue to fall.

PRICES U.S. STEEL HOT-ROLLED SHEET (1995-2008E)



Source: SG Cowen

The increase in global steel production capacity should stabilize the market at a lower price, as it has in past business cycles. Much of the new capacity is being put into place in China. In fact, China is becoming a net exporter of steel. Given China's competitive advantages (specifically, favorable exchange rates and low labor costs), and also the fact that analysts[3] expect that the prices for steel will continue to decrease the next five years, U.S. steel suppliers may be facing a challenging future. China may have an incentive to reduce its prices, putting pressure on other steel producers—including U.S. steel producers.

The Department of Defense consumes only about 0.3 percent of total U.S. steel production (primarily specialty steel such as Aermet® 100 or 300M for landing gear systems). The remaining 99.7 percent is sold for non-DoD applications. As a very small consumer of steel, the Department is significantly influenced by overall U.S. steel business trends because these same U.S. suppliers provide the specialty steel that is critical to U.S. weapon systems.

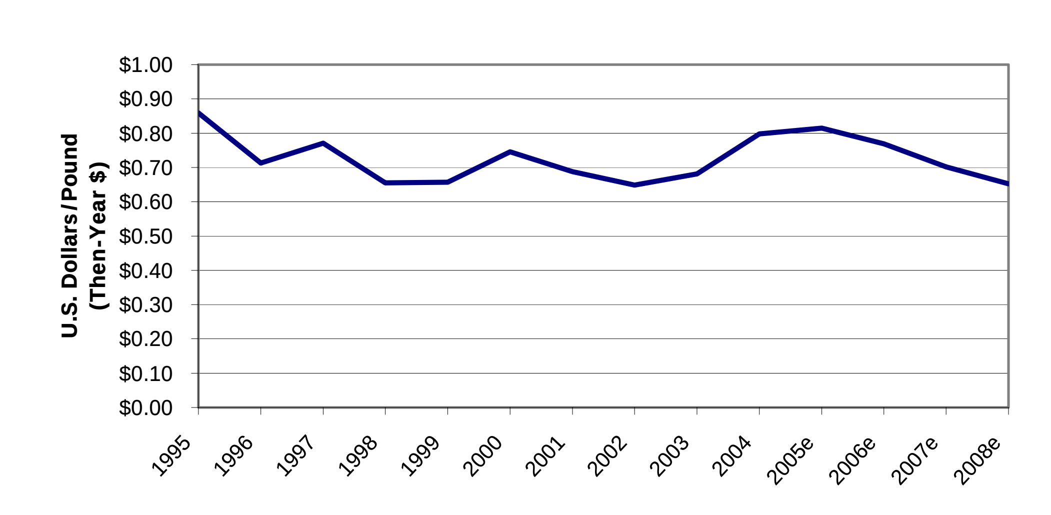
ALUMINUM

As illustrated in the graphic on the following page, a recession in 2001 led to a decline in consumer demand and exacerbated the impact of production overcapacity, weakening prices. The aluminum market is particularly sensitive to demand for consumer products. Economic recovery in the United States and elsewhere, as well as rising demand in China, led to an upswing in aluminum consumption and prices beginning in late 2003. As was the case for steel, the price increased substantially in 2004. Rising prices for alumina (a major raw material input in aluminum) contributed to this trend. Prices began

[3] Source: Morgan Stanley Equity Research.

to moderate in 2005[4] and are expected to decline beginning in 2006 as worldwide production meets and begins to surpass demand.

PRICES U.S. ALUMINUM (1995-2008E)



Source: SG Cowen

Large transport aircraft such as the C-17 use significant quantities of aluminum (aluminum represents 73 percent of C-17 aircraft weight). As was the case for steel, the Department's consumption of aluminum pales (three percent of annual U.S. production) in comparison to consumer product use and commercial aircraft production. Globally, demand for both steel and aluminum should continue to increase over the next two to three years.

High aluminum prices and tight supply conditions likely will continue through 2005. After 2005, new capacity is projected to offset demand increases and weaken prices. China also is becoming a larger factor in world production capacity for aluminum. With new Chinese production capability online, in 2002, China became a net exporter of aluminum. Similar to the steel situation, China may have an incentive to reduce its aluminum prices as worldwide production capacity outstrips demand putting pressure on other aluminum producers—including U.S. aluminum producers.

TITANIUM

The graphic on the following page depicts the price history of the titanium ingot primarily used in aerospace applications.[5]

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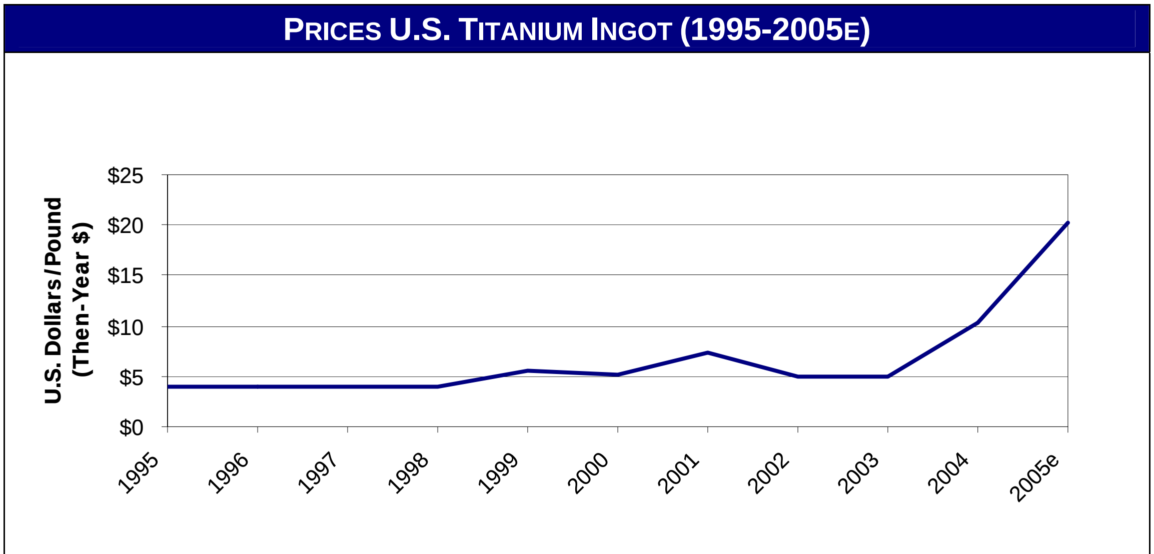
[4] End-of-year information indicates that aluminum prices actually increased slightly. Prices are still expected to decline in 2006.

[5] Defense Federal Acquisition Regulations Supplement (DFARS) 252.225-7014 generally requires any specialty metals (including titanium and certain steel alloys) incorporated in articles delivered under DoD contracts to be melted in the United States.



Source: U.S. Geological Survey Minerals Information

The price of titanium was relatively stable until 1998. Increased industrial, medical, sporting goods, and other commercial application demand drove higher prices, beginning in 2001. Prices dropped 33 percent in 2002 after the 9/11 events and a steep decline in the commercial aerospace sector (a major end-user), caused titanium mills to slow production significantly. In early 2003, global titanium demand began to increase rapidly primarily due to the recovery of the commercial aerospace sector, driving up prices for finished titanium, as well as for titanium scrap and raw materials. The price of titanium ingot doubled in 2004 and doubled again in 2005. There is little data or forecast information available for future titanium production capacity increases or future prices. Consequently, this study does not attempt to project titanium prices beyond 2005.

Prices for titanium scrap also have risen considerably, with China becoming one of the major consumers of titanium scrap for use in its production of carbon steel and certain grades of stainless steel. Capacity expansions for titanium are more capital intensive and technically challenging than steel and aluminum production expansion. Titanium is not traded on the worldwide commodities markets and price, supply, and demand projections are extremely limited. However, market conditions likely will encourage higher prices at least until currently-planned large capacity expansions come online in 2007 or later.

Titanium constitutes a large percentage of the structural weight and propulsion systems of current and future advanced tactical aircraft (such as F-22A and F-35), making it a critical material to the Department.

Defense applications for titanium consume a moderate fraction of domestic titanium production—approximately 16 percent. Commercial aerospace, industrial, automotive, and sporting goods applications consume the remaining 84 percent. Commercial aerospace applications alone account for more than 40 percent of domestic titanium consumption.[6]

As a result, the U.S. titanium industry is linked closely to the volatile demand cycle of commercial aerospace. Most demand growth likely will come from increased use (as a percentage of aircraft weight) of titanium in new commercial aircraft designs and increased aircraft production orders as the aerospace industry recovers.[7] DoD titanium demand likely will significantly increase over the next seven to ten years as the F-22A, F-35, and other military aircraft are added to or replace the existing fleet.

Although titanium's light weight, excellent strength-to-weight ratio, and corrosion resistance make it desirable for many high-performance applications, very high production and processing costs retard titanium's use in a broader range of applications.[8] If additional material production cannot be brought online to assist in driving down the cost, the Department may face higher prices over the long-term which will result in higher unit costs for tactical aircraft.

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[6] Information provided by *Titanium Industry Study,* Northrop Grumman Information Technology, August 2004, and *Titanium Industrial Base Assessment,* Defense Contract Management Agency/Industrial Analysis Center, June 2003.

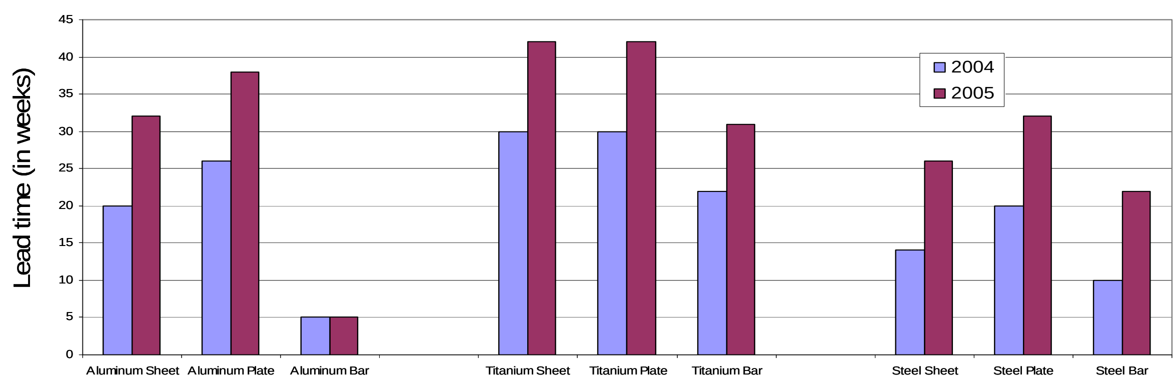
[7] For more detail on this, see the graphic on page 11 (amount of titanium used in current and new commercial aircraft) and the charts on pages 31-32 (production of commercial and military aircraft).

[8] Researchers are trying to develop new methods for extracting titanium from its ore, forming it into sponge, and forming the sponge into ingot. If successful, new methods could significantly lower the processing costs of titanium, lowering the price and allowing a wider range of applications, including broader use in the automobile industry, and for consumer and medical applications.

SCHEDULE TRENDS

The impact of increased world demand for metals also is evidenced by increased material lead times in military programs.[9] In 2004, steel sheet lead times increased 86 percent (from 14 weeks to 26 weeks), steel plate 60 percent (from 20 weeks to 32 weeks), and steel bar 120 percent (from 10 weeks to 22 weeks). Aluminum product lead time growth has been more erratic. Sheet and plate lead times increased 60 percent (from 20 weeks to 32 weeks) and 46 percent (26 weeks to 38 weeks), respectively. Aluminum bar lead times remained constant at about five weeks. Titanium lead times have grown about 40 percent across the range of products (30 weeks to 42 weeks for both titanium sheet and plate, and 22 weeks to 31 weeks for titanium bar).

RAW MATERIAL LEAD TIMES



Source: Various defense contractors

If lead times continue to increase, DoD weapons programs may be forced to start long lead parts procurements earlier than the current span of twelve months prior to start of final assembly. Increasing long lead span times could force the Department to adjust program funding across the Department—reducing weapon system deliveries, stretching-out programs, and impacting logistic support. The Department is evaluating the cause of these trends. If the increased lead times for DoD applications are the result of U.S. material suppliers allocating tight production resources to non-DoD applications, the Department can use the Defense Priorities and Allocations System (DPAS) to direct deliveries to critical DoD applications first.

ADDITIONAL EVIDENCE TO DATE

In addition to the market research described earlier, ODUSD(IP) representatives visited a major aerospace firm to assess impacts of metals price increases on their contracting strategies, costs structures, and material lead-times. Additionally, a major titanium

[9] Lead time is defined as the amount of time between the supplier's placing of an order for material and the supplier's receipt of the material ordered.

supplier has expressed significant concern about business dislocations resulting from major price increases.

LOCKHEED MARTIN

__Lockheed Martin (LM)__ is the prime contractor/systems integrator and final assembler for several major aircraft weapon systems: F-16; C-130J; and F-22A. LM also will build the multi-Service, multi-mission F-35 Joint Strike Fighter that will enter production in 2011. These aircraft use large quantities of steel, aluminum, and titanium. To temper the near-term impact of increased material demand, LM has:

- *Secured long-term agreements for high usage materials. Price risk remains for certain items.*
- *Established right-to-buy provisions that allow its subcontractors to use LM Aero long-term agreements with materials suppliers.*
- *Obtained support commitments from metals suppliers.*
- *Flowed DPAS clauses down to subtiers to secure priority delivery.*

The F-35 Joint Strike Fighter (JSF) represents Lockheed Martin (LM) Aeronautics' core fighter business for the foreseeable future. LM has taken a proactive position to study and understand the commodities market and the effect that Chinese demand may have on present and future prices. It also is working with its suppliers and putting into place material management risk mitigation actions and plans. For example, LM held right-to-buy training conferences with suppliers to share insights. In some cases, LM formed partnerships with suppliers and worked with them to purchase certain commodities to hedge against future price increases. It also is utilizing the DPAS throughout its supply chain to secure priority performance for its defense applications and continues to watch raw material markets closely. LM sees the current increased demand from China as a short-term market "bump" as producers will respond to limited availability and price volatility by increasing capacity over the next 18-24 months.

WYMAN GORDON

Wyman Gordon (WG) is the predominant producer of large titanium forgings for a variety of defense systems—including F-22A, F-35, F/A-18, and C-17. Its large forging facility is located in Grafton, MA. WG did not enter into long-term agreements with its suppliers and is facing substantial military business pressures on firm fixed-price subcontracts. Some of its customers have not allowed WG to pass through to them WG's significantly increased titanium prices, putting pressure on overall WG profitability.

PART II

INFLUENCES ON THE METALS MARKETS

Some observers of metals markets have suggested that Chinese demand is the major cause of rising metals prices. Chinese demand is among the major factors in the rising global demand for steel and aluminum, but not for titanium.

WORLD ECONOMIC RECOVERY

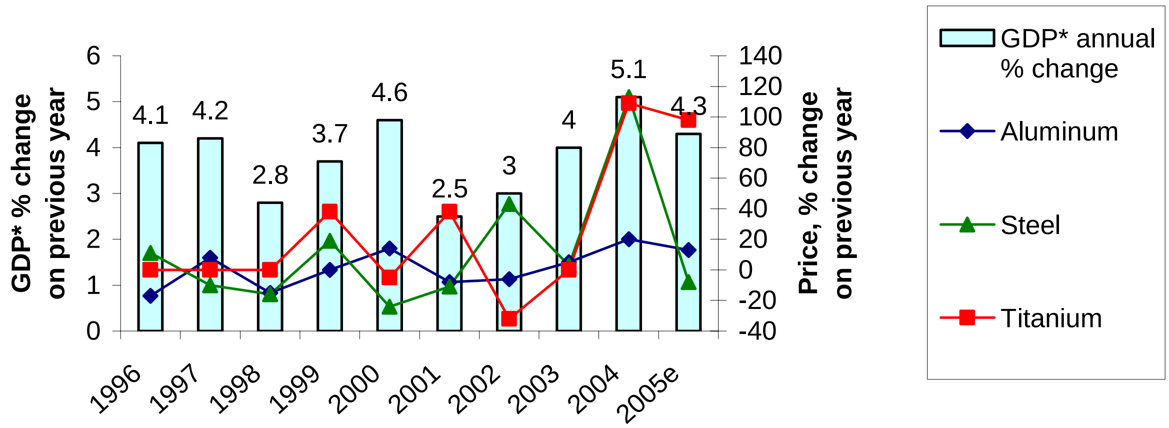
Economic growth increases spending power, thus increasing demand for consumer products and the factories and equipment used to produce additional goods and infrastructure improvements. Industrial metals are major inputs in infrastructure development and automobile, aerospace, and other manufacturing segments.

2004 was a year of unusually rapid global economic growth. Leading this trend were the U.S. recovery after the 2001 economic downturn and China's continuing expansion into global markets. However, growth was not limited to these two countries. According to the World Bank, developing countries experienced the fastest growth in three decades, and the sluggish economies of Japan and Europe performed better than recent averages. Growth in the remainder of the developed world also was strong.[10] This widespread growth led to dramatic increases in metals demand and consequently put pressure on global supplies, driving down inventories and pushing up prices.

The link between economic growth and metals demand, leading to fluctuating prices, is a common feature of economic cycles. There is a strong link between economic growth (measured in gross domestic product (GDP) for the world) and changes in prices of aluminum, and to a lesser degree with steel. There is no apparent correlation with titanium prices. The chart on the next page shows International Monetary Fund (IMF) data on world GDP growth along with the prices of aluminum, steel, and titanium.

[10] World Bank, *Prospects for the World Economy*, April 2005.

ECONOMIC GROWTH AND METALS PRICES
WORLD (1996-2005E)



*Gross Domestic Product, measured in constant dollars

Sources: International Monetary Fund and U.S. Geological Survey

For every year over the past ten years (1996-2005), a rising (falling) rate of world growth correlated with rising (falling) aluminum prices. However, for steel, only five times over the ten-year span does the correlation track. World growth correlates with titanium prices only two times over that period. There is a strong correlation between economic growth and aluminum prices because a higher percentage of aluminum is used in consumer products (such as beverage cans and automobiles), whereas a comparatively higher percentage of steel is used in infrastructure and a higher percentage of titanium is used in commercial and military aerospace applications. Demand for consumer products is more susceptible to GDP fluctuations than demand for infrastructure or aerospace products.[11]

Major observers of the world economy such as the World Bank, the Organisation for Economic Co-operation and Development (OECD), and the IMF forecast world GDP growth rates over the next several years to fall approximately one half to one percentage point lower than the highs of 2004, due to factors such as high oil prices and rising interest rates. In other words, the world economy is expected to grow at a slower

[11] A more thorough investigation of the link between GDP growth and metals prices would include examining whether or not there is a correlation between the *magnitudes* of price changes and GDP growth and investigating the influence of other factors affecting metal supply as demand, such as raw material availability, oil prices, breakthroughs in technology, etc. Such in-depth analysis is beyond the scope of this study.

rate than was measured in 2004, implying slower growth in metals demand and a decrease, or slower increase, in prices.[12]

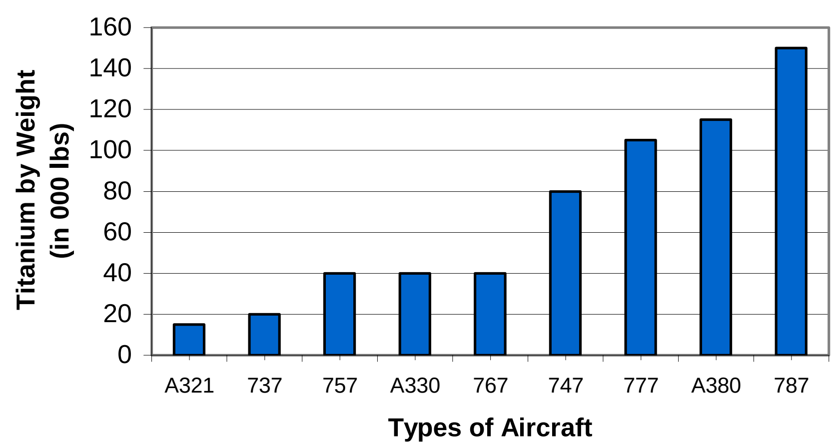
Commercial Aerospace Rebound

Whereas economic growth has been the main driver of aluminum demand and, to a lesser degree, steel demand, there virtually is no correlation between economic growth and titanium demand. Steel and aluminum are commodities produced by many companies and used in a vast range of applications in numerous sectors. Titanium, conversely, is not sold on market exchanges and is characterized by small market size, few producers, and one dominating end-use sector. Aerospace accounts for about half of world titanium consumption and over half (50-65 percent, varying annually) of U.S. titanium consumption.

Because aerospace accounts for so much of titanium demand, volatile swings in this industry drive large cycles in the titanium market. The post-9/11 downturn in commercial aerospace weakened titanium demand considerably. An upswing in defense aerospace began to mitigate this decline in 2003. In 2004, titanium demand soared due to a rebound in commercial aerospace. Over the next several years, the rebound in commercial aerospace is expected to continue.

Furthermore, in the coming years several new commercial aircraft designs such as the Boeing 787 and the Airbus A380, using a large amount of titanium as illustrated by the chart below, will enter production.

Titanium in Current and Future Aircraft (Buy Weight)



Source: RMI Titanium Company

These developments will strengthen titanium demand, likely keeping prices high.

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[12] Major events such as large-scale supply interruptions or dramatic increases in input (i.e., ore, coal, electricity) costs would result in increased prices.

CHINA'S RISING SHARE OF GLOBAL DEMAND FOR METALS

As U.S. and non-U.S. firms outsource manufacturing (especially automobiles) to China for lower-cost labor, metals demand also shifts to China. This doesn't necessarily increase overall world demand, but it inflates China's share of that demand.

In addition, China's rapid industrialization and extraordinary growth of the last several years has to a large extent contributed to the rising global demand for metals, which in turn has fed rising world prices. China's growth depends significantly on the availability of commodities, including the metals discussed in this study, which are key inputs into growing sectors such as infrastructure, construction, transportation, and manufacturing.

China is using government funds to purchase equity interests in non-Chinese companies owning and producing critical raw materials. It appears that China is doing this to ensure the availability of these raw materials to support increased Chinese infrastructure and manufacturing requirements.

Chinese consumption of steel and aluminum has grown much faster than consumption in the rest of the world in recent years.[13] Chinese consumption of titanium remains relatively unchanged as a percentage of worldwide consumption.

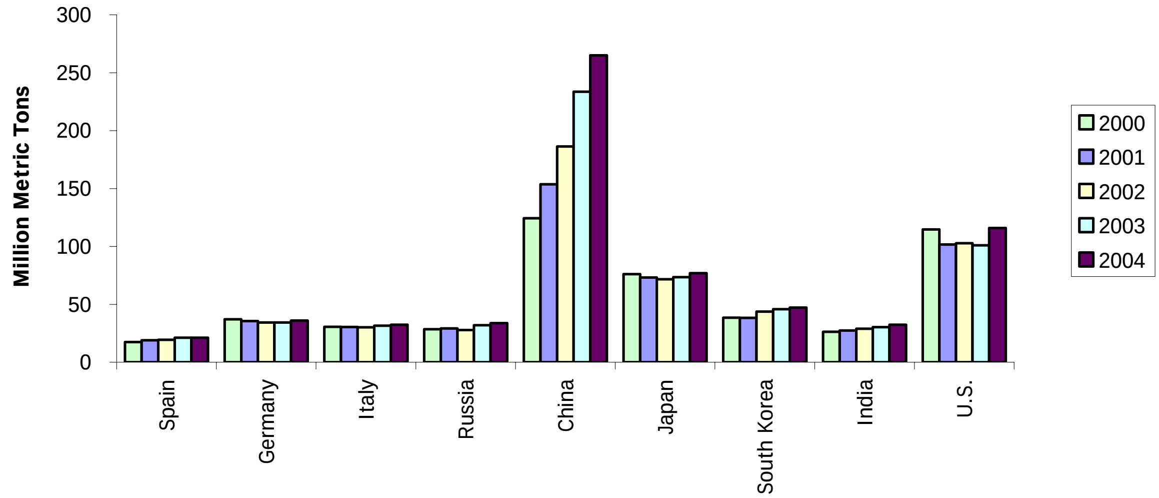
STEEL

For most of the 1990s, China's steel consumption hovered near that of the United States, about 100 million metric tons (mmt) per year. In 2000, however, as U.S. steel consumption began to decline slightly, China's began to rise steeply—almost doubling from 1999 to 2003. Growth has continued, with consumption rising 15 percent in 2004 alone (to 274 mmt).

[13] Chinese planners are forecasting over capacity in the steel and aluminum industry and have placed a temporary moratorium on steel plant construction.

The chart below illustrates rapidly rising Chinese steel demand from 2000-2004, as compared to relatively flat consumption in other major steel-consuming countries.

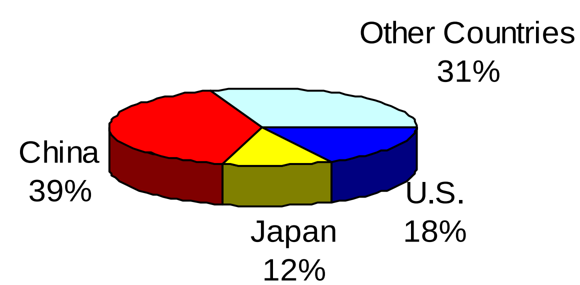
WORLD DEMAND-STEEL (2000-2004)



Source: International Iron and Steel Institute

As a consequence, China today is the world's largest consumer of steel by a large margin. It accounts for more than one-third of global steel demand, surpassing the combined total of the U.S. and Japan, the second- and third-place consumers respectively, as shown in the chart opposite.

WORLD STEEL DEMAND 2004



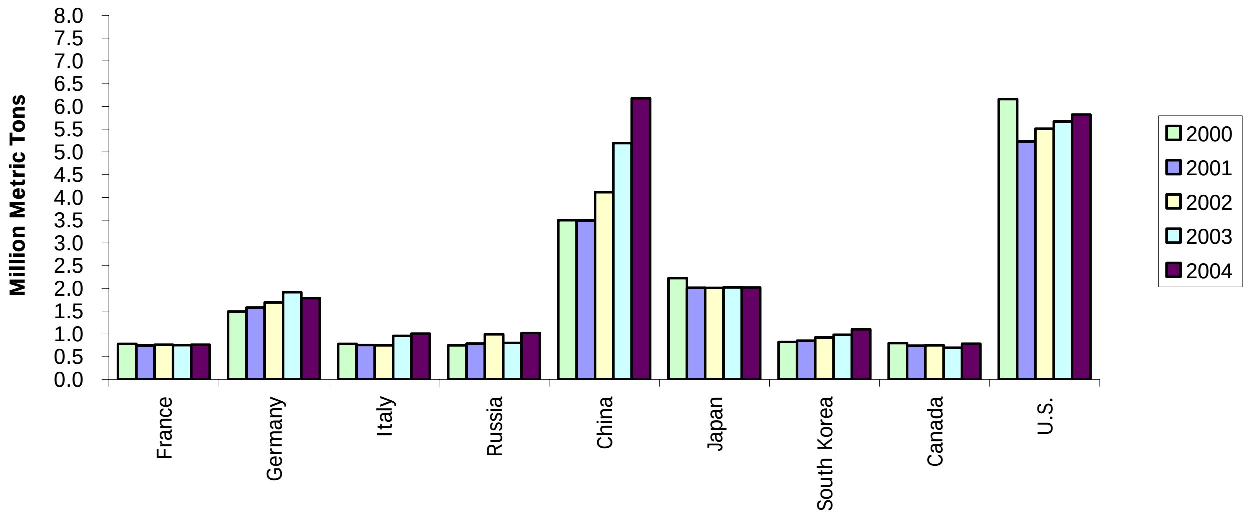
Source: International Iron and Steel Institute

The upward pressure on global steel prices, to a large extent driven by Chinese demand, has begun to reverse. In 2003-2004, world steel demand growth outpaced production, and prices rose accordingly. In response to elevated demand, steelmakers around the world have expanded capacity. This phenomenon is most apparent in China. Though China historically has been a major steel importer, steady capacity expansions have not only made China the world's largest steel producer but China also is becoming a net exporter of steel.

ALUMINUM

Aluminum has followed a similar path. Chinese aluminum consumption also has been rising steadily and surpassed U.S. consumption in 2004, as shown in the chart below.

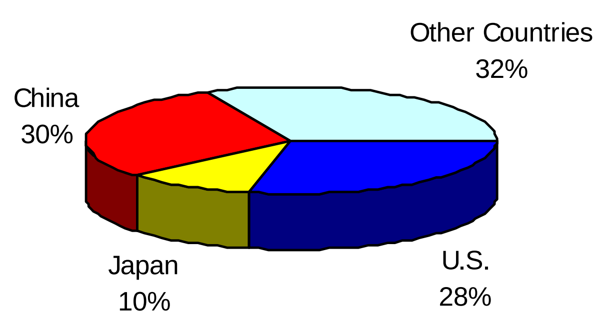
WORLD DEMAND—ALUMINUM (2000-2004)



Source: World Bureau of Metal Statistics

China's aluminum consumption has risen more than 60 percent in the last three years. China now consumes around 30 percent of the world's aluminum. The United States is second as shown in the chart opposite.

WORLD ALUMINUM DEMAND 2004



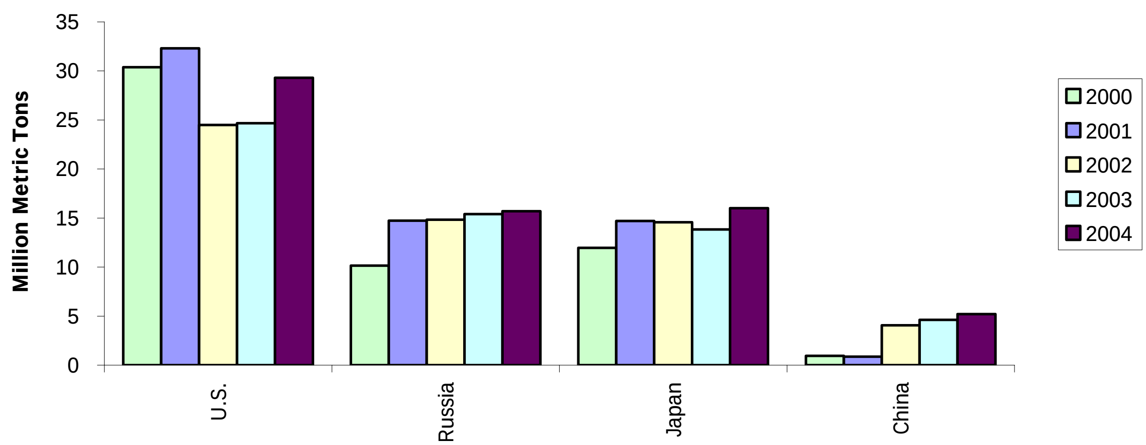
Source: World Bureau of Metal Statistics

Chinese aluminum production also is growing quickly and has surpassed domestic demand. China became a net exporter of aluminum in 2002. The Aluminum Corporation of China expects domestic demand for aluminum to triple by 2020.

TITANIUM

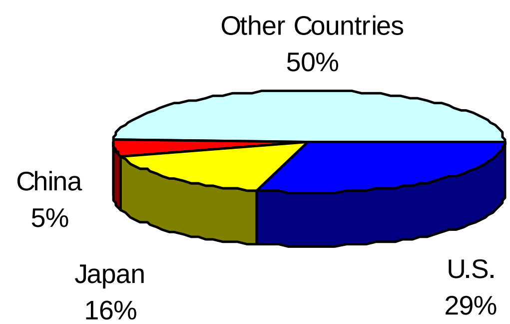
The chart below illustrates that Chinese demand for titanium has increased substantially since 2000, but China's demand still substantially trails that of other major industrial nations. This information indicates that Chinese titanium demand likely was not the primary driver in increased titanium prices in 2004.

WORLD DEMAND—TITANIUM (2000-2004)



Source: U.S. Geological Survey Minerals Information

WORLD TITANIUM DEMAND 2004



Source: International Iron and Steel Institute

China's demand for titanium in the world market is small compared to that for aluminum and steel, although it is growing. The chart opposite indicates that China is a relatively small direct consumer of titanium—only about five percent of world demand in 2004. Indirectly, Chinese marine, airplane, and industrial power generation purchases also are adding to worldwide demand for titanium.

Today, China is a relatively minor producer of titanium. Its capability is on the increase. According to the National Bureau of Statistics, China produced almost 8,400 tons of titanium sponge through November 2005, almost an 85 percent increase over the previous year.

CONCLUSION: METALS MARKETS INFLUENCES

Due to its rapid development, industrialization, and extraordinary growth over the last several years, China today is the world's largest consumer of steel and aluminum. Chinese demand is among the major factors in the rising global demand for steel and aluminum, but not for titanium.

PART III

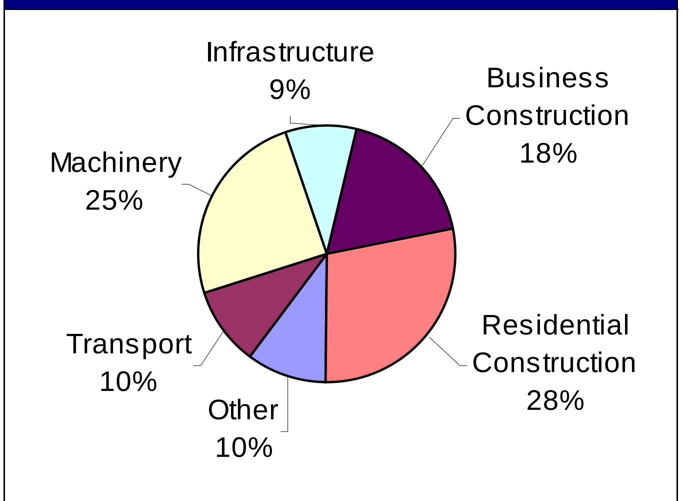
DRIVERS OF CHINESE DEMAND

China is experiencing rising average incomes, rapid urbanization, growing entrepreneurship, and an economy increasingly open to trade.[14] These factors are dramatically increasing Chinese demand for buildings, cars, appliances, consumer goods, and improvements to transport and communication systems, all of which are dependent on metals.

Construction and infrastructure are the largest factors affecting steel and aluminum demand in China.[15] China is in the midst of a major historical shift from a largely agrarian to an increasingly urban society. Though the majority of Chinese citizens still live in rural areas, fifteen million people are expected to join the urban population annually for the next five years, many attracted by larger job markets in cities.

Additionally, since the creation of a commercial housing market and a commensurate tapering off of government-supplied residences in the late 1990s, Chinese citizens increasingly are buying their own homes. Both urbanization and housing privatization have encouraged widespread construction of new apartment buildings. Rising consumer spending and growing entrepreneurship have led to increased construction of new shopping centers, storefronts, and office buildings. China's construction boom translates into increasing demand for steel and aluminum. Steel is used extensively in building; and aluminum is used to make windows and doors.

CHINA: STEEL CONSUMPTION BY END USE 2003



Sources: Rio Tinto and Morgan Stanley Equity Research

As shown in the chart opposite, infrastructure and construction (residential and business) accounted for over half (55 percent) of Chinese steel consumption in 2003.[16] As China develops, consumption patterns are expected to shift gradually to more closely resemble those of developed countries. The construction boom is far from over, however. The majority of people in China still live in small, low-quality residences, and many analysts

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[14] This section drew heavily on information in a report by Andy Rothman, "China eats the world," CLSA Asia-Pacific Markets, Spring 2005.

[15] Data is widely available on China's use of steel and aluminum but is much more limited for titanium. End uses of titanium in China will be dealt with briefly and separately at the end of this section.

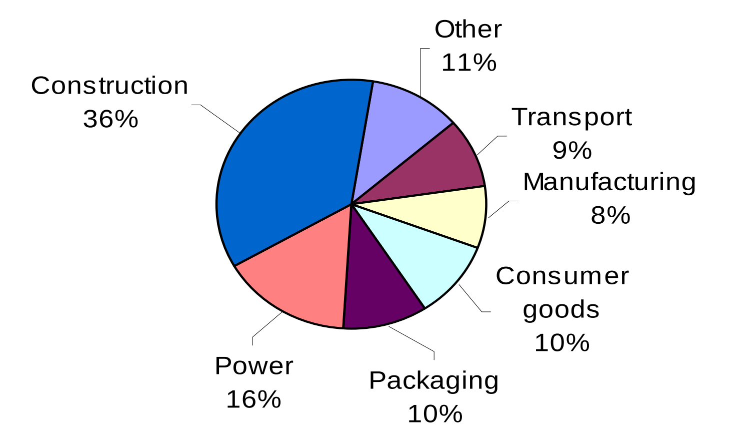
[16] Estimates vary, as do most statistics on China. The Chinese steel producer Baosteel states that construction accounts for 67 percent of Chinese demand for steel. World Steel Dynamics estimates 54 percent, BHP Billiton 68 percent, and Rio Tinto 55 percent.

expect that as incomes rise, the demand for new, more spacious housing will be strong for years to come.

Another noteworthy factor affecting steel demand is the production of machinery, the second largest consumer of steel in China (18-25 percent).[17] Steel required for machinery grew by a factor of 22 from 1998 to 2002, fueled both by increasing demand for machines to produce goods in China, and by China's emergence as a major exporter of machine tools.

The third largest consumer of steel in China is the automobile industry.[18] Car owners in China still are relatively rare compared to developed countries, but Chinese are buying private cars in increasing numbers. Additionally, China is beginning to develop an automobile export market. Auto production increased 12 percent in 2004 to 2.3 million cars. Increasing production has led Chinese steelmakers to begin producing high-quality steel sheets for use in the auto industry.

CHINA: ALUMINUM CONSUMPTION BY END USE 2003



Source: Morgan Stanley Equity Research

The chart opposite shows that construction applications represent 36 percent of Chinese aluminum consumption. In the developed economies of Europe, Japan, and the United States, construction accounts for only 20-25 percent of aluminum demand. In these countries, transportation (primarily automobiles) and packaging (primarily aluminum cans) account for the bulk of aluminum demand (approximately 30-40 percent and 15-30 percent, respectively). The power sector is the second most important factor driving Chinese aluminum demand, accounting for 16 percent of consumption.[19] Aluminum consumption in this sector increased 70 percent from 1999 to 2003. Other important factors include appliances (especially air conditioners), packaging (primarily beverage cans), and transport (automobiles and other).

Rising average incomes are an important, if indirect, factor driving up metals demand. Per capita urban income almost tripled between 1990 and 1995, increased by almost 50

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[17] Morgan Stanley estimates 25 percent; Andy Rothman puts the figure at around 18 percent.
[18] Andy Rothman states that autos consume six percent of Chinese steel; Morgan Stanley estimates ten percent for "transport," a broader category.
[19] Both Morgan Stanley and Andy Rothman cite this figure.

percent more in the next five years, and increased again by half from 2000 to 2004.[20] Over the last several years, an urban middle class of 50-60 million households has emerged. This number is tiny as a percentage of China's population of 1.3 billion, but it already amounts to a market the size of Japan's, and it is growing quickly. Rising wealth has boosted retail sales (which grew nine percent in 2003 and ten percent in 2004) mostly due to growing sales of cars, appliances, and other goods which are heavy users of metals.

Chinese demand for metals likely will continue to increase substantially in the medium- to long-term, though most likely at a slower rate of increase than has been seen in the last few years. The Chinese government has recently adopted various macroeconomic measures intended to rein in high levels of investment and GDP growth due to fears of overheating the economy. While these measures should have some moderating effects on the Chinese economy, many analysts expect GDP growth levels to range between seven and nine percent during the next five years—lower than the nine to ten percent average seen over the last decade or more, but still quite high by world standards. Because of the correlation between GDP growth and aluminum and steel demand, China's demand, especially for aluminum, should continue to increase, for years to come.[21]

Accurate information on China's use of titanium is limited. According to Chinese media sources, before the period of economic reform began in 1978, China produced titanium in secret and only for military purposes. Now, according to these sources, China's top titanium producer (Baoji Titanium Industry, known as Baoti) is publicly-owned, in part, and titanium is used in consumer products (such as Ray-Ban sunglasses) and aircraft parts.[22]

THE CHINESE RESOURCE STRATEGY IN CONTEXT

In assessing likely developments involving Chinese demand for these major metals, it is important to account for the extent to which modernization is a strategic objective of 21st century China. This modernization will drive sector demand increases in transportation, infrastructure, and other commercial sectors—which, in turn, will fuel increasing demand for major metals of interest to the Department for the foreseeable future.

Because of the government's drive to modernize China, natural resource strategies—among them, securing access to major metals needed for modernizing the Chinese economy—are an important element in China's overall comprehensive national strategy.

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[20] The national average is now $1,135. It is $2,000 in the major cities of Shanghai, Beijing, and Guangzhou.

[21] According to Andy Rothman, citing Komesaroff, since 1980 there has been a very strong correlation (98 percent) between per capita primary aluminum consumption in China and the country's real GDP per capita. This means that as Chinese incomes have risen, their aluminum consumption has risen as well. The link between GDP and aluminum demand, discussed earlier in this section, thus is especially true for China.

[22] "Rising demand for titanium drains supply as prices soar," *Shenzhen Daily,* June 9, 2005.

ECONOMIC EXPANSION

Chinese leaders appear to see economic growth and development as key to ensuring social stability and increasing national power. China's resource strategy for securing raw materials abroad, which includes signing long-term contracts with suppliers around the world, is one element of its overall approach to economic growth. Other elements include expanding foreign trade, increasing inward and outward foreign direct investment, reforming the banking sector, cautiously adjusting currency policy, signing free trade agreements, and overhauling state-owned enterprises.

POLITICAL STANDING

Chinese leaders view the next two decades as a window of opportunity for development. They seek legitimacy at home and influence abroad that will foster and not hinder this development. Domestically, their strategy includes pursuing reunification with Taiwan, raising living standards, and maintaining social stability. Their strategy abroad includes prestige initiatives (such as the 2008 Beijing Olympics), increased participation in international organizations (United Nations, World Trade Organization), resolving border disputes, and strengthening bilateral relations with key states. This last element in particular supports China's need for cooperative relationships with countries rich in the raw materials key to industrial development.

MILITARY CAPABILITY

Chinese leaders see a modern military as vital for protecting the homeland, deterring foreign aggression and Taiwanese independence, protecting economic resources, and projecting Chinese influence abroad. Their strategy includes reorganizing and streamlining their armed forces, expanding their naval capacities beyond traditional coastal defense, increasing strategic missile forces, and preparing for high-technology limited warfare. China's military capability relates to its resource strategy in that it could use military force or threats to bolster its claims to potentially resource-rich territory in the region, as it has done on limited levels in the past. For more information on this topic, see the Department's *Annual Report to Congress on The Military Power of the People's Republic of China 2005*, published in July 2005.

CHINA'S QUEST FOR RAW MATERIALS

China is seeking to fill its need for stable metal supplies both with domestic and foreign sources.[23] It has significant, proven domestic reserves of certain minerals, some of which are listed in the chart below:

[23] The information in this section is derived from unclassified Defense Intelligence Agency data, Chinese media sources, U.S. Geological Survey Metals Information, and other sources.

China's Share of Proven World Reserves of Selected Minerals		
Mineral	**Selected Uses**	**China's Share (%)**
Manganese	Steel and aluminum production	11
Lead	Batteries, ammunition	16
Silver	Mirrors, electrical uses, photography	10
Vanadium	Titanium alloys for use in jet engines and airframes	38
Copper	Electrical uses (power transmission, wiring, etc.)	6
Source: U.S. Geological Survey Minerals Information		

China also has huge discovered reserves of iron ore (a key component of steel production), but most of it is low-grade (averaging around 30 percent iron content), and China is expected to import around 240 million tons this year—more than any other country—although output is expected to reach 370 million tons. Geologists believe that China also has significant untapped reserves of iron, as well as copper, nickel, and other materials. These resources, however, are hard to exploit due to remote locations and poor infrastructure, which often means exploitation is not yet economically viable. China is increasing investment in domestic mining and appears to be seeking foreign investment as part of this process. Analysts expect, however, that it will be several years before these companies set up operations.

Because domestic mineral reserves are insufficient to meet China's growing demand, China is reaching out globally to obtain raw materials at their source. This strategy is in many ways akin to China's more well-known "go global" approach to energy resources, whereby China has signed long-term contracts for oil and natural gas with various countries around the world. African and Latin American countries are a particular focus as resources for metals production. China's quest for raw materials involves a menu of tactics.

STRATEGIES IN CHINA'S GLOBAL SEARCH FOR METALS

Imports:

China imports materials for metals production from the following countries, sometimes signing long-term contracts to guarantee future supply:

- Alumina: Australia, Brazil, India, Jamaica, Kazakhstan, United States, Venezuela
- Bauxite (used in aluminum production): Brazil, Congo, India, Indonesia, Kazakhstan, Mongolia, Myanmar, Philippines, Russia, Zambia, Vietnam
- Iron Ore: Australia, Brazil, India, Peru, South Africa, United States

Joint Ventures:

China has signed joint ventures with suppliers in other countries including the United States, Brazil, Zambia, Myanmar, Australia, and Mongolia, for mining iron, gold, copper, nickel, manganese, and zinc; and production/refining of iron, alumina, and aluminum.

Infrastructure projects in less-developed countries:
China is building bridges, roads, ports, power plants, etc. in certain underdeveloped, mineral-exporting countries, mostly in Africa. These measures make it easier to transport the materials to China. Furthermore, this strategy creates an incentive for exporting countries to cooperate with China, especially when faced with a lack of investment from other developed countries.

China's Specialty Steel Capability[24]

As part of its overall modernization efforts, China is modernizing its steel industry. According to some sources, China has the capability to produce certain specialty steels and alloys for use in both commercial and defense applications. China's steel industry historically has been notorious for its inefficiency and low-quality products. China is improving manufacturing technology and production methods to meet world standards, build new facilities and upgrade existing ones, and add new equipment.

For example, China's stainless steel production is rising to meet bourgeoning internal demand. Chinese consumption of stainless steel has quadrupled in the last ten years, from approximately one to four million tons per year. China's stainless steel

Baosteel: China's Steel Giant

Baosteel, the foremost steel company in the leading steel-producing country, is expanding overseas.

Chinese companies increasingly are investing abroad, with raw materials companies leading this trend as they seek to meet bourgeoning Chinese needs for energy, metals, and other materials. Baosteel (Shanghai Baosteel Group Corporation) is a state-owned company at the forefront of these efforts for iron and steel. It is negotiating the largest overseas investment ever made by a Chinese company—a deal to import iron ore from Brazil's Companhia Vale do Rio Deco (CVRD), the world's largest iron ore maker.

A Fortune 500 company, Baosteel produced over 20 million tons of steel in 2004, up 7.8 percent from the previous year. It is expected to double its capacity by 2010 to become the world's number three producer. Unlike many Chinese steel companies, Baosteel operates with state-of-the-art technology, equipment, and management. It focuses on high value-added products and its markets include automobiles, shipbuilding, appliances, and construction.

One problem Baosteel faced recently is difficulty obtaining raw material inputs, such as iron ore and coal—both widely available in China but inadequate for the country's needs due to poor quality and skyrocketing demand. Baosteel's overseas expansion is partially intended to secure imports of these materials. Furthermore, the expansion will move some production overseas for future re-exportation to China, a shift the Chinese government hopes will meet China's steel needs while reducing the environmental damage and energy strain caused by the domestic steel industry. The Baosteel-CVRD deal is expected to triple iron ore imports to 20 million tons annually by 2010. The companies also are considering building a joint venture steel mill in Brazil.

Yahoo! Finance, The Economist,
Xinhua News Agency, and Business Week

[24] The information in this section is derived from unclassified DoD information.

production is increasing as well. It virtually is equal to Chinese demand. Stainless steel is used in a variety of defense aerospace applications, including landing gear and engines.

In this process of modernization, China is relying both on domestic research and development efforts and foreign assistance in the form of joint ventures. Firms in France, Germany, Italy, Japan, South Korea, Sweden, and the United States have helped modernize China's steel industry. Baosteel (which is owned by the Chinese government) leads China's domestic steel research and development. It is China's largest and most profitable steel manufacturer and the fourth largest steel company in the world.

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Part IV

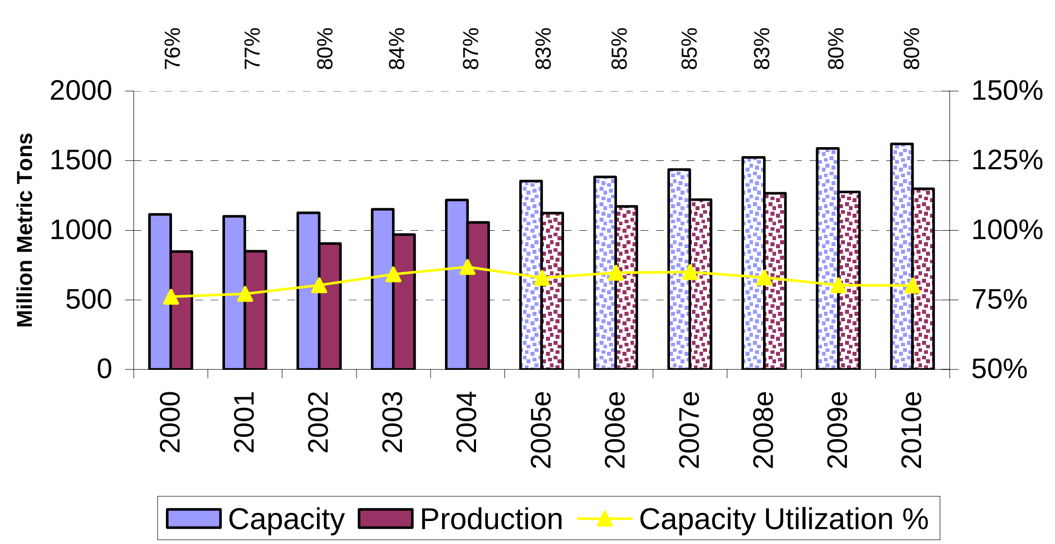
Metal Markets Adjusting to New Demand

Steel: Prices In Decline

2004 was a landmark year for the steel industry, as profits jumped in response to booming world demand and elevated prices. But because global GDP growth is expected to slow from record 2004 rates, and Chinese demand growth may cool slightly from the breakneck pace in 2003-2004, market forecasters expect a slowdown or even reversal to the recently observed upward trends.

As discussed in Part I, steel prices peaked in late 2004 and began to fall. This decline has continued. A combination of moderating world demand growth rates and increasing world capacity has reduced price pressures in global steel markets.

Annual World Steel Capacity and Production
Crude Steel



Source: Metal Strategies Incorporated

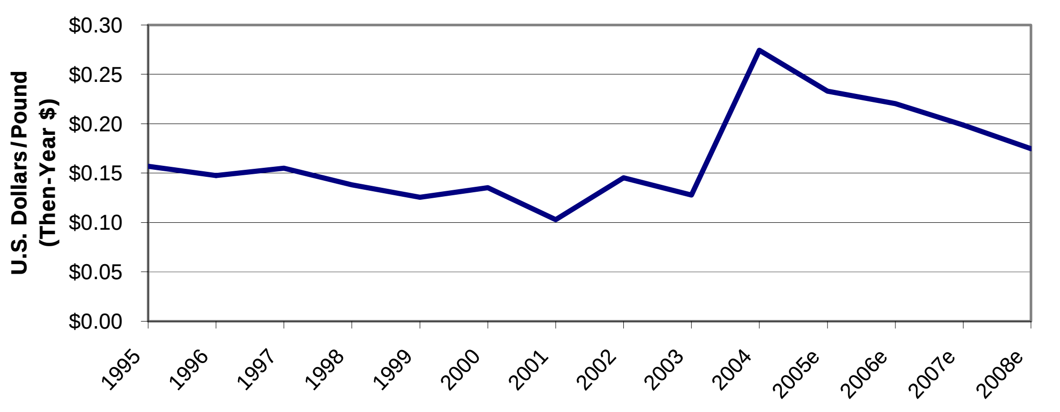
The chart above summarizes data on world crude steel capacity and production over the last five years and provides estimates through 2010. According to this data, in 2004, 1.057 billion metric tons of steel were produced worldwide. World steel production is predicted to rise to 1.265 billion metric tons in 2008 and 1.297 billion in 2010, an increase of 240 million metric tons (23 percent) over 2004 levels. Capacity in 2004 was 1.217 billion metric tons and is expected to rise to 1.523 billion in 2008 and 1.620 billion in 2010, an increase of 403 million metric tons (33 percent) over 2004 levels. With capacity expected to rise approximately twice as much as production between 2004-

2010, capacity utilization rates[25] will fall. This decline should have a dampening affect on prices.

Utilization rates ranged from a low of 76 percent in 2000 to a high of 87 percent in 2004. When compared with price trends for steel, low capacity utilization rates (76-77 percent) in 2000-2001 are associated with low and falling prices in the same period. Likewise, the price peak in 2004 followed high and rising capacity utilization rates in that year. Strong demand both allows companies to charge higher prices and also provides an incentive to operate at higher rates of utilization.

The correlation between price and capacity utilization rates can be seen by comparing the increasing capacity utilization during the period 2000-2004 depicted in the graph on the previous page with generally increasing steel prices during that same period as shown in the chart below.

PRICES U.S. STEEL HOT-ROLLED SHEET (1995-2008E)

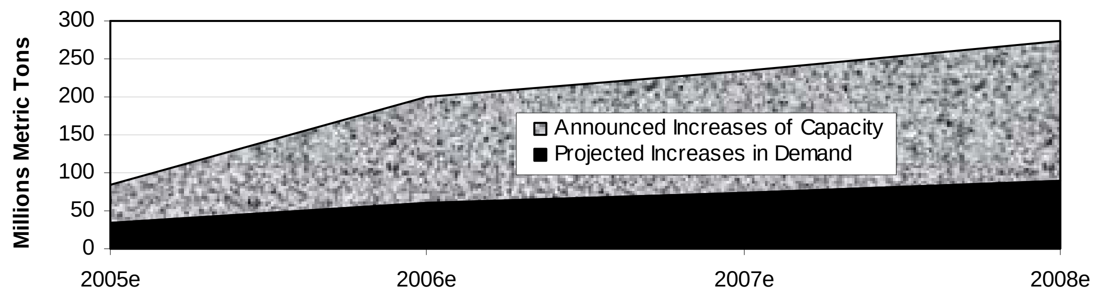


Source: U.S. Geological Survey Minerals Information

The dramatic upward trend in prices witnessed in recent years likely is unsustainable because steelmakers around the world are responding with plans for substantial capacity expansions. An OECD report documented these planned expansions and compared them with demand projections through 2008. The OECD report forecasts world steel capacity to rise from 1.18 billion metric tons[26] in 2004 to 1.46 billion in 2008. According to this report, announced global capacity increases far exceed projected increases in steel demand during this time period, with the gap growing larger year by year, as shown in the chart on the following page.

[25] Production divided by capacity.
[26] World capacity is difficult to measure precisely; estimates vary among reporting agencies.

INCREASE IN STEEL CAPACITY VS INCREASE IN DEMAND FOR STEEL



Source: Organization for Economic Cooperation and Development

If projected capacity increases are manifested and demand rises as predicted, the global steel industry will face significant overcapacity in the coming years. Demand projections assume moderate economic growth. If growth projections are lower than expected, steel demand will weaken and overcapacity conditions will be even more pronounced.

China accounts for the largest portion of planned capacity expansions in the 2004-2008 period. The OECD calculated the total for announced capacity expansions worldwide between 2004-2008 at 280 mmt, an increase of around 24 percent. China is predicted to account for 109 mmt of that increase, or almost 40 percent of the total. Morgan Stanley Research forecasts for global capacity are slightly lower, predicting a 220 mmt increase from 2004-2008. These estimates expect 129 mmt of the increase (59 percent) to come from China. Analysts have projected that China, already the world's largest steel producer and consumer; will continue to expand capacity and production significantly in the next several years, outpacing its own consumption growth. This could lead to increasing Chinese steel exports, which could drive down global steel prices and put competitive pressure on U.S. steelmakers. As discussed in Part II, it appears that Chinese planners have recognized this potential overcapacity situation and have placed a temporary moratorium on steel plant production.

Other countries in the developing world are planning to expand steelmaking capacity significantly in the next several years. According to the OECD, Indian steelmakers have announced plans to add 48.5 million tons of capacity by 2008, an increase of well over 100 percent from 2004 levels. In 2004, India consumed around 30 million tons of steel and produced over 40 million tons, exporting the excess. Because planned capacity expansions would outpace expected demand growth, these expansions, if manifested, will significantly increase Indian exports.[27]

[27] It is uncertain to what extent announced expansions will be manifested. Some forecasts for Indian capacity are significantly lower than those of the OECD. For example, Morgan Stanley Research expects Indian capacity to increase by 13 mmt between 2004-2008 (a 28 percent increase). Though more moderate, Morgan Stanley estimates, like those of the OECD, expect Indian steel production and capacity

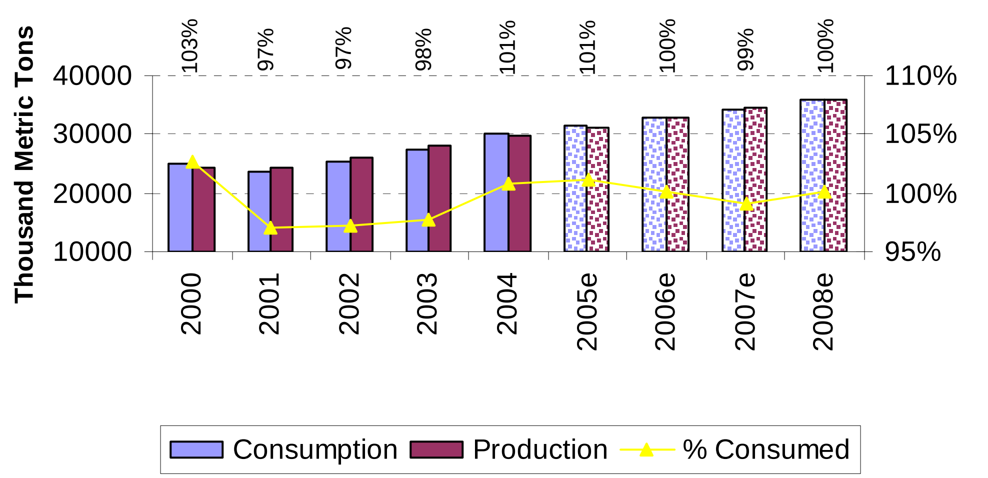
The OECD predicts similar situations in Brazil and Russia also tending to dampen prices. For example, Brazil's planned capacity expansions by 2008 total 62 mmt, most of which would be exported.[28] While not on the scale of planned Chinese increases, developing countries' expansions, in aggregate, could exacerbate future overcapacity. Several uncertainties remain, for example, the extent to which announced capacity expansions will actually be manifested, the percent of capacity expansions that will be utilized in actual production, and the future pace of world economic growth.

In summary, future steel price increases are not likely.

ALUMINUM: MARKET REMAINS TIGHT IN SHORT TERM

Like steel, high growth in consumption drove price increases for aluminum in 2004, both in China and globally. World consumption grew 9.3 percent in 2004, surpassing expectations. Chinese consumption grew 16.8 percent that year, also higher than expected. Unlike steel, aluminum markets are expected to remain tight well into 2006. In the short term, aluminum prices are unlikely to follow the steeply declining trajectory witnessed and projected for steel.

WORLD ALUMINUM CONSUMPTION AND PRODUCTION



Sources: World Bureau of Metal Statistics, Morgan Stanley Research Equity

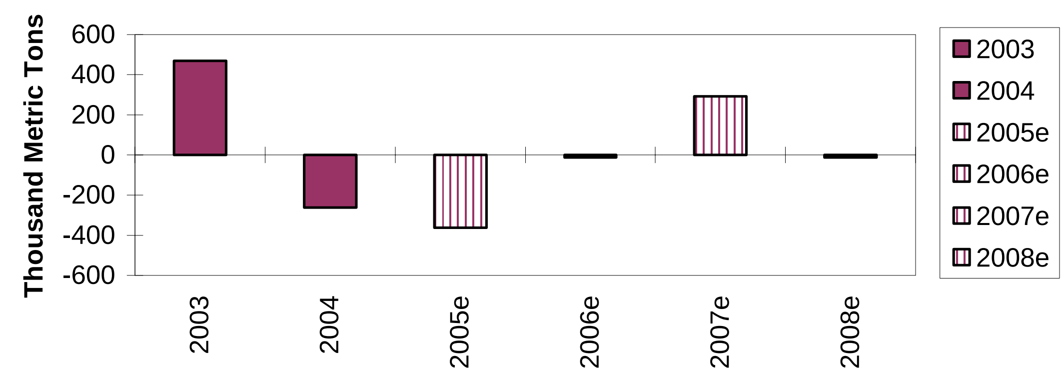
growth to outstrip consumption growth by an increasingly large margin through 2008, which would lead to export growth.

[28] The OECD report, "Capacity Expansion in the Global Steel Industry," January 2005, provides anecdotal data on planned Russian capacity expansion which stretched beyond 2008. Morgan Stanley Research used "former USSR" as a category and estimated a 25 mmt capacity increase from 2004-2008 for this region. However, production was expected to increase by only seven mmt. When compared with current data and forecasts for consumption, these estimates imply growing overcapacity and continuous export levels .

The chart above shows historical information and forecasts comparing world aluminum production and consumption. In 2004, according to Morgan Stanley estimates, world aluminum consumption (30.1 million tons) equaled approximately 101 percent of production (29.8 million tons). In other words, previously existing surpluses were used to meet world demand. According to these estimates, deficit conditions will persist in 2005-2006, reversing in 2007 when supply (production) is once again forecasted to exceed demand (consumption).

Deficit and surplus information and forecasts are represented in the chart below.

WORLD ALUMINUM SURPLUS/DEFICIT 2003-2008E



Source: Morgan Stanley Research Equity

Since the early 1990s (not shown), the world aluminum market generally has been in surplus due to excess supply beginning after the breakup of the U.S.S.R. when the former Soviet Union began exporting large amounts of aluminum. Recently, increasing Chinese exports (China became a net exporter in 2002) and the U.S. recession in 2001 (which caused demand for aluminum to decline) added to world oversupply conditions. Consumption rebounded in 2003, and, as shown above, aluminum markets were in deficit in 2004, driving up prices.

Chinese aluminum output may contract in 2005 due in part to government macroeconomic measures designed to slow investment in the aluminum industry. Increasing difficulty obtaining alumina and electricity shortages also are afflicting many Chinese factories. High alumina and energy costs are affecting U.S. producers as well. The combined effect may be slowing global aluminum production growth in 2005. In 2006, however, aluminum capacity is expected to increase. Morgan Stanley forecasted a four mmt increase in capacity in 2006, which would bring aluminum markets into surplus in 2007.

Prices therefore can be expected to remain stable in 2005 and into 2006, declining in 2007 as aluminum markets are once again characterized by excess supply. Like other commodity markets, however, the aluminum market is cyclical, generally following economic growth cycles. Unexpected recession or boom in the world economy would cause either moderation or exacerbation of these trends.

TITANIUM: PRICES LIKELY TO REMAIN HIGH

Compared to global production and consumption of steel and aluminum, the available data and forecasts for titanium are very limited. It is therefore difficult to make quantitative predictions for the future direction of the titanium industry. The United States consumes well over 100 mmt of steel and six mmt of aluminum per year, while the U.S. annual demand for titanium is in the range of 40,000 metric tons. This comparatively low demand, combined with an expensive and highly technical production process and high capital costs act as a barrier to entry for new firms. The result is a limited number of U.S. titanium suppliers.

Titanium sponge is produced by only one U.S. company, TIMET.[29] The United States is a net importer of sponge. Its main import sources are Kazakhstan (48 percent), Japan (39 percent), and Russia (12 percent). Collectively, these three countries account for around three-quarters of global production. China and the Ukraine also produce titanium sponge. Although the minerals used to produce titanium are widely available, the complex and costly nature of processing the raw materials first into titanium sponge and then into ingot have limited the number of global producers.

Titanium ingot is produced by only three U.S. companies: TIMET, Allegheny Technologies, and RMI Titanium. Those three companies produce 54 percent of the world's titanium ingot.[30] The United States is a net exporter of titanium ingot and wrought products. Other major producers include China, France, Germany, Italy, Japan, Russia, and the United Kingdom.

Titanium demand primarily is a product of military and commercial aerospace applications, and industrial and consumer applications. The biggest impact on titanium demand and the prices of titanium is commercial aerospace.

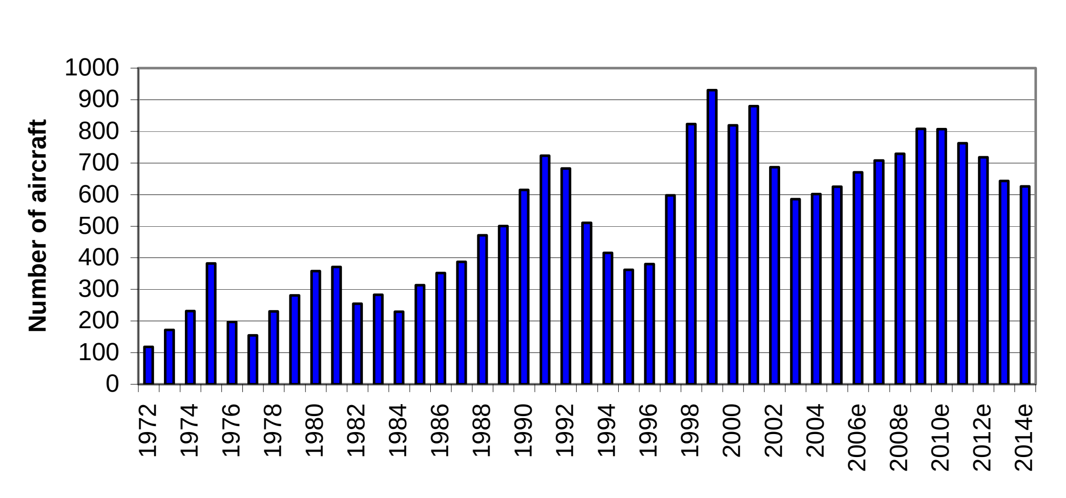
AEROSPACE APPLICATIONS

Commercial Aerospace

The tables on the next page shows historical and predicted data for production of large commercial aircraft[31] in the period 1972-2014.

[29] However, Allegheny Technologies has announced plans to restart its titanium sponge facility.
[30] Titanium ingot is nearly finished titanium metal which has been melted from titanium sponge and then is wrought into titanium mill products such as bar, sheet, wire and rod.
[31] Large commercial aircraft refer to those aircraft with a capacity of more than 100 seats.

PRODUCTION OF LARGE COMMERCIAL AIRCRAFT 1972-2014E

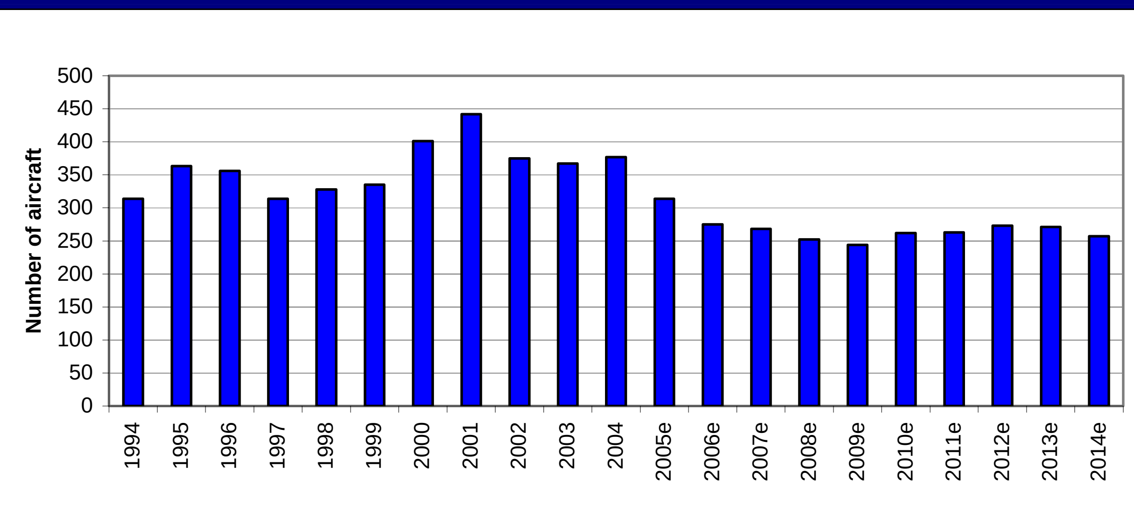


Source: Teal Group

The market for large commercial aircraft is cyclical. In the period 1995-2003 (the last cycle) a total of 6,000 large aircraft were produced worldwide. For the period 2004-2014 (the next cycle) that number is expected to exceed 7,000. As noted on page 11, the titanium content of large commercial aircraft also is increasing.

In 2005, the Teal Group published a 10-year overview that forecasted that the number of regional aircraft[32] to be produced in the period 2005-2014 will decrease the first five years, followed by a three year increase after which the numbers of produced aircraft will decline again. Still, in that period almost 2,700 regional aircraft are expected to be produced worldwide.

PRODUCTION OF REGIONAL COMMERCIAL AIRCRAFT 1994-2014E



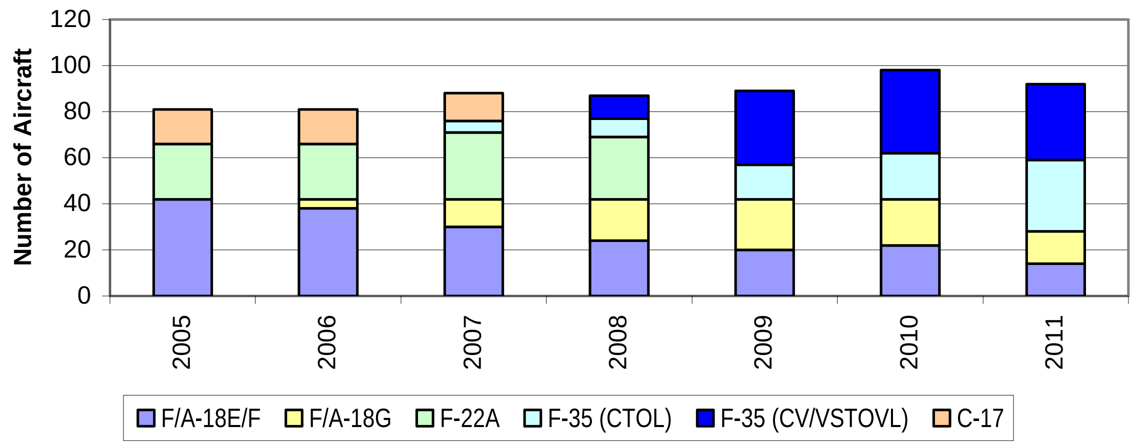
Source: Teal Group

32 Regional commercial aircraft refer to those aircraft with a capacity of less than 100 seats.

Military Aerospace

The table below summarizes the number of military aircraft types on which this report focuses (C-17, F/A-18E/F/G, F-22A and F-35) that will be produced in the United States in the period 2005-2011.[33]

PROJECTED PRODUCTION OF MILITARY AIRCRAFT 2005-2011



Source: OUSD(AT&L), Defense Acquisition Management Information Retrieval (DAMIR) database (Dec 2005)

As shown in the chart below, a total number of almost 34,000 commercial and military aircraft are expected to be produced worldwide in the period 2005-2014.

NUMBER OF COMMERCIAL AND MILITARY AIRCRAFT PRODUCED IN 2005-2014E

Units Produced	2005e	2006e	2007e	2008e	2009e	2010e	2011e	2012e	2013e	2014e	Total
Business Jets	524	552	608	696	765	780	737	693	689	718	6,762
Commercial Jetliners	625	670	708	729	808	807	762	718	643	626	7,096
Fighters	242	282	285	297	313	321	330	323	294	268	2,955
Rotorcraft	820	839	834	881	943	992	941	947	989	983	9,169
Military Transports	50	59	50	50	53	54	65	56	53	49	539
Regional Aircraft	314	275	268	252	244	262	263	273	271	257	2,679
Trainers/Light Attack	165	163	163	188	195	192	144	134	131	112	1,587
Other	285	305	320	310	335	345	310	300	290	285	3,085
Total Units	**3,025**	**3,145**	**3,236**	**3,403**	**3,656**	**3,753**	**3,552**	**3,444**	**3,360**	**3,298**	**33,872**

Sources: Teal Group, Lockheed Martin, and OUSD(AT&L), DAMIR database (Dec 2005)

As most of these aircraft consume a considerable amount of specialty metals, it is therefore likely that there will be increased demand for titanium in coming years. Unless

[33] This report does not reflect aircraft quantity changes described in the February 2006 Quadrennial Defense Review.

unforeseen technological breakthroughs significantly reduce the cost of producing titanium, increasing demand for titanium in the coming years is likely to keep prices high.

NON-AEROSPACE APPLICATIONS

Industrial applications account for about 70 percent of non-aerospace titanium demand.

Industrial Use of Titanium

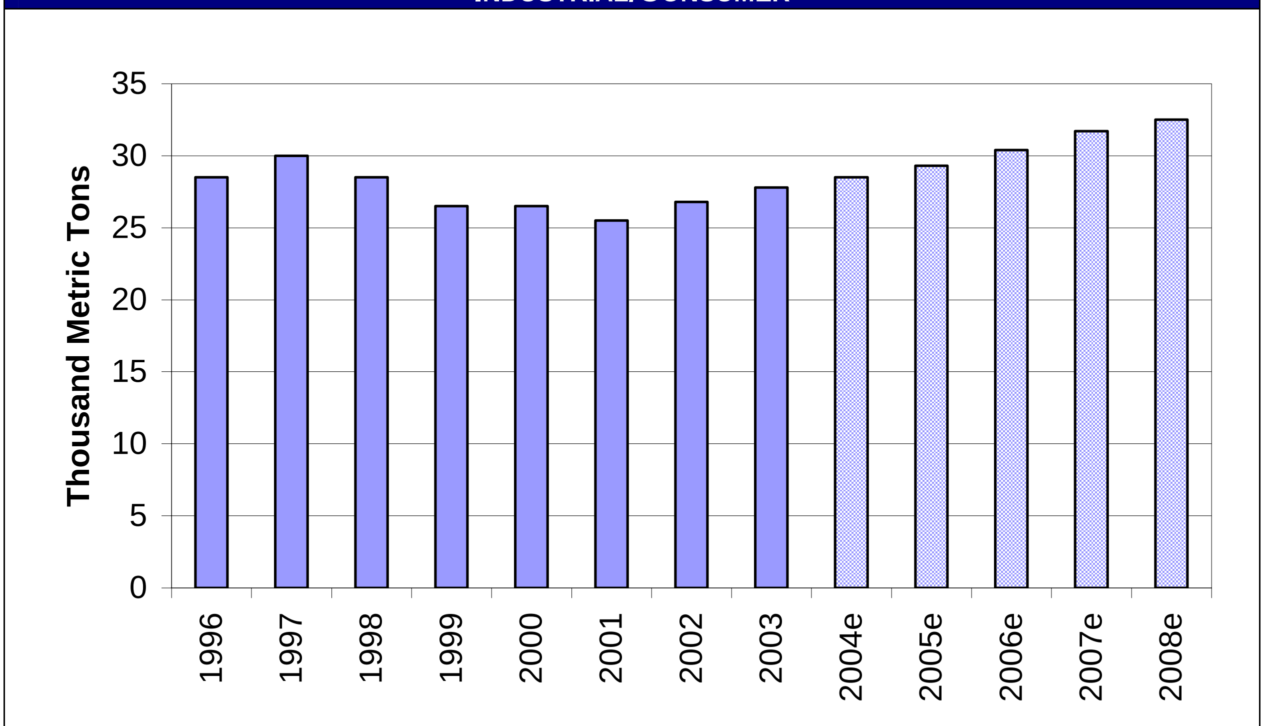
The use of titanium has expanded in recent years to include applications in nuclear power plants, food processing plants, and offshore oil and gas industries. In addition, titanium is used in the production of computers, electronics, medical prostheses, and surgical instruments.

Consumer Use of Titanium

Titanium also increasingly is used for consumer applications such as golf clubs and sunglasses.

The chart below summarizes actual and projected titanium mill product shipments for industrial and consumer applications for 1996-2008. Titanium mill product shipments are projected to increase at least through 2008.

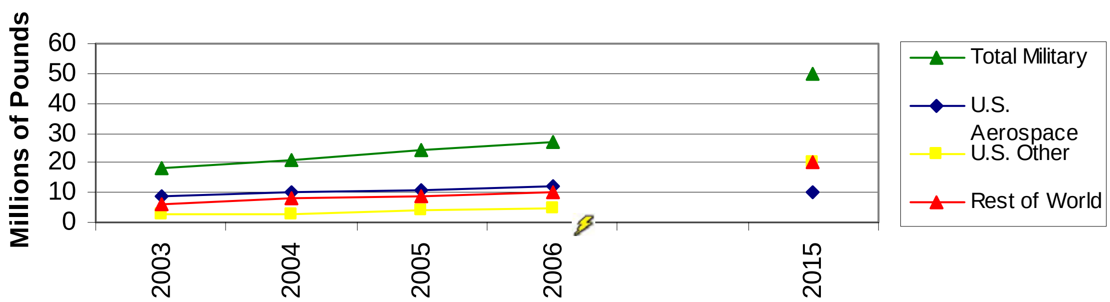
TITANIUM INDUSTRY MILL PRODUCT SHIPMENTS
INDUSTRIAL/CONSUMER



Sources: JTS Statistics, Public documents and TIMET internal estimates

Global, military use of titanium is expected to increase significantly between now and 2015[34], as shown in the next chart.

GLOBAL MILITARY TITANIUM CONSUMPTION



Source: RTI International Metals Inc.

If these forecasts prove accurate, this increasing demand for titanium in the military, commercial aerospace, and industrial/commercial sectors will substantially increase global titanium consumption. There usually is a lag time between demand increases and titanium producers' ability and willingness to expand capacity. In the short-to-medium term this likely will continue upward pressure on titanium prices. In the medium-to-long term, capacity should expand to meet demand. Unforeseen advances in technology could lower the costs of producing titanium and could put downward pressure on prices.

Conclusion: Metals Markets Adjusting to New Demand

Both the steel and aluminum markets are adjusting to the increased demand by expanding capacity, which will result in stabilized or declining steel and aluminum prices. Titanium demand also is increasing. However, there is little information available on projected worldwide titanium production or production capacity. Therefore, it is not clear whether titanium prices are likely to increase, stabilize, or decline.

[34] RTI developed this information for strategic planning purposes. It does not include annual consumption projections for the years 2007-2014. Accordingly, it does not depict increased U.S. military aerospace titanium consumption during this period for the F-35. F-35 production will peak in 2014 and level off thereafter for 10 years before production declines. Additionally, F/A-18G production is projected to peak in 2009. The RTI information therefore masks this production and corresponding increased titanium consumption.

PART V

LIKELY IMPACT ON THE DOD BUDGET

The table below shows, for the representative aircraft types, the number of aircraft to be procured by the Department in the period 2005-2014e.

NUMBER OF MILITARY AIRCRAFT TO BE PROCURED IN 2005-2011								
Aircraft Type	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Total**
C-17	15	15	12	0	0	0	0	**42**
F/A-18E/F	42	38	30	24	20	22	14	**190**
F/A-18G	0	4	12	18	22	20	14	**90**
F/A-22	24	24	29	27	0	0	0	**104**
F-35 (CTOL)	0	0	5	8	15	20	31	**79**
F-35 (CV/ VSTOVL)	0	0	0	10	32	36	33	**111**
Source: OUSD(AT&L), Defense Acquisition Management Information Retrieval (DAMIR) database (Dec 2005)								

The table below summarizes the steel, aluminum, and titanium material fly weights and material buy weights for these aircraft.

MATERIAL FLY/BUY WEIGHTS OF C-17, F/A-18E/F/G, F-22A, AND F-35								
Aircraft Type	**C-17**	**F/A-18E**	**F/A-18F**	**F/A-18G**	**F-22A**	**F-35 (CTOL)**	**F-35 (VSTOVL)**	**F-35 (CV)**
Airframe[35] Weight (lbs)	274,000	30,718	31,526	32,755	43,341	28,975	32,555	34,468
Steel								
Material Fly Weight (lbs)	18,052	1,535	1,576	1,637	2,131	176	192	178
Material Buy Weight (lbs)	90,260	9,210	9,456	9,822	49,000	1,189	1,741	1,503
Ratio Fly/Buy Weight (%)	20.0	16.7	16.7	16.7	4.3	14.8	11.0	11.8
Aluminum								
Material Fly Weight (lbs)	131,782	3,399	3,489	3,625	4,576	4,153	4,294	4,483
Material Buy Weight (lbs)	1,317,820	67,980	69,780	72,500	119,000	54,117	52,915	58,377
Ratio Fly/Buy Weight (%)	10.0	5.0	5.0	5.0	3.8	7.7	8.1	7.7
Titanium								
Material Fly Weight (lbs)	16,247	2,412	2,476	2,572	9,989	1,945	2,036	3,251
Material Buy Weight (lbs)	81,235	14,472	14,856	15,432	239,736	13,273	12,592	26,010
Ratio Fly/Buy Weight (%)	20.0	16.7	16.7	16.7	4.2	14.7	16.2	12.5
Source: OUSD(AT&L)/Defense Systems								

[35] These weights are for the airframe only. Total aircraft weight also includes engines, avionics, etc.

The amount of metals to be procured for the production of an aircraft (Material Buy Weight) is significantly greater than the actual amount of that same metal present in the delivered aircraft (Material Fly Weight). For example, contractors must acquire almost 240,000 pounds of titanium to produce a single F-22A—for which the titanium content of the finished components totals less than 10,000 pounds. In other words, 4.2 percent of the total amount of titanium purchased for one F-22A is present in the completed aircraft. The remaining 95.8 percent of the purchased titanium ends up as scrap to be sold for recycling. Overall, scrap rates for these aircraft range from a "low" of 80 percent (20 percent Fly/Buy ratio) for steel and titanium for the C-17 to a high of 96.2 percent (3.8 percent Fly/Buy ratio) for aluminum for the F-22A.

Aircraft designers seek to design components with high strength, but with minimal weight. To achieve this, designers often choose metal plates and forgings for structural components. However, forgings and mill suppliers generally ship components in rough finished forms due to limitations in providing near-net shapes. Instead, parts undergo finish machining to gain the proper dimensional tolerances and to meet weight requirements for the airframe. As a result, 80-95 percent of the metal may be machined from the rough forging and end up as scrap. Given today's manufacturing processes, scrap of this magnitude is unavoidable. However, DoD and industry initiatives are focusing on the reduction of scrap by using advanced manufacturing techniques to create near-net shape components with wrought properties. Currently, military aircraft prices generally are not adjusted for costs recovered by contractors from the sale of scrap metals. Nevertheless, costs associated with recovered scrap reduce overhead rates which ultimately affect the prices the Department pays for its aircraft. Therefore, this study reduces projected aircraft prices by the value of estimated pro-rated recovered scrap costs.

The C-17, F/A-18, F-22A, and F-35 use specialty metals and aerospace alloys of steel, aluminum, and titanium. In December 2005, representative prices for aerospace alloys for these three metals were:

- steel : $ 3.00 per pound
- aluminum : $ 5.00 per pound
- titanium : $ 25.00 per pound

In the same period, the estimated scrap prices for these three metals were:

- steel : $ 0.14 per pound
- aluminum : $ 0.65 per pound
- titanium : $ 15.00 per pound

The table on the following page summarizes unit recurring flyaway costs, material buy weights, current metal and scrap prices, the absolute value and relative value (percentage) of the specialty metals, within each aircraft type and the net unit price.

COST MATERIAL BUY WEIGHT OF C-17, F/A-18E/F/G, F-22A, AND F-35

Aircraft Type	C-17	F/A-18E	F/A-18F	F/A-18G	F-22A	F-35 (CTOL)	F-35 (VSTOVL)	F-35 (CV)
Unit Recurring Flyaway Cost ($)	197,600,000	53,000,000	54,500,000	62,700,000	133,100,000	44,500,000	58,700,000	61,700,000
Steel								
Material Buy Weight (lbs)	90,260	9,210	9,456	9,822	49,000	1,189	1,741	1,503
Price steel alloy 2005e ($)	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Cost Material Buy Weight ($)	270,780	27,630	28,368	29,466	147,000	3,567	5,223	4,509
Cost Material as % of unit recurring flyaway cost	0.14%	0.05%	0.05%	0.05%	0.11%	0.008%	0.009%	0.007%
Price steel scrap 2005e ($)	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Amount of scrap (lbs)	72,208	7,675	7,880	8,185	46,869	1,013	1,549	1,325
Value of scrap ($)	10,109	1,075	1,103	1,146	6,562	142	217	186
Net unit price of steel ($)	**260,671**	**26,556**	**27,265**	**28,320**	**140,438**	**3,425**	**5,006**	**4,324**
Aluminum								
Material Buy Weight (lbs)	1,317,820	67,980	69,780	72,500	119,000	54,117	52,915	58,377
Price aluminum alloy 2005e ($)	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Cost Material Buy Weight ($)	6,589,100	339,900	348,900	362,500	595,000	270,585	264,575	291,885
Cost Material as % of unit recurring flyaway cost	3.33%	0.64%	0.64%	0.58%	0.45%	0.61%	0.45%	0.47%
Price aluminum scrap 2005e ($)	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Amount of scrap (lbs)	1,186,038	64,581	66,291	68,875	114,424	49,964	48,621	53,894
Value of scrap ($)	770,925	41,978	43,089	44,769	74,376	32,477	31,604	35,031
Net unit price of aluminum ($)	**5,818,175**	**297,922**	**305,811**	**317,731**	**520,624**	**238,108**	**232,971**	**256,854**
Titanium								
Material Buy Weight (lbs)	81,235	14,472	14,856	15,432	239,736	13,273	12,592	26,010
Price titanium alloy 2005e ($)	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Cost Material Buy Weight ($)	2,030,875	361,800	371,400	385,800	5,993,400	331,825	314,800	650,250
Cost Material as % of unit recurring flyaway cost	1.03%	0.68%	0.68%	0.62%	4.50%	0.75%	0.54%	1.05%
Price titanium scrap 2005e ($)	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Amount of scrap (lbs)	64,988	12,060	12,380	12,860	229,747	11,328	10,556	22,759
Value of scrap ($)	974,820	180,900	185,700	192,900	3,446,205	169,920	158,340	341,385
Net unit price of titanium ($)	**1,056,055**	**180,900**	**185,700**	**192,900**	**2,547,195**	**161,905**	**156,460**	**308,865**

Sources: OUSD(AT&L)/Defense Systems and Industrial Policy

The relative values of the specialty metals are quite small. For steel, those percentages range from 0.007 percent (seven one thousandths of one percent) for the F-35 (CV) to 0.14 percent (14 hundredths of one percent) for the C-17. For aluminum, those percentages range from 0.45 percent for the F-35 (STOVL) and the F-22A to 3.33 percent for the C-17. For titanium, the percentage rates vary from 0.54 percent for the F-35 (STOVL) to 4.5 percent for the F-22A.

The chart on the next page summarizes the results of a sensitivity analysis examining various potential metals price increases. This report forecasts that aluminum and steel prices will not increase significantly in the future. However, if aluminum prices were to increase by 25 percent, the largest unit price increase would be $1,455,000 for the C-17 and result in a total increase buy cost of $61,091,000 over 42 aircraft. If steel prices were to increase by 25 percent, the largest unit price increase would be $65,000 for the C-17 and result in a total increase buy cost of $2,737,000 over 42 aircraft. Titanium price increases may be more likely. A 25 percent titanium price increase for the F-22A would increase unit price by $637,000 and the total buy by $66,227,000 over 104 aircraft.

POTENTIAL NET INCREASES IN AIRCRAFT COSTS (THOUSANDS OF FY05 $)

Aircraft Type	Steel				Aluminum				Titanium			
	Base	*10% increase*	*25% increase*	*50% increase*	*Base*	*10% increase*	*25% increase*	*50% increase*	*Base*	*10% increase*	*25% increase*	*50% increase*
C-17												
Base	261				5,818				1,056			
Increase/Unit		26	65	130		582	1,455	2,909		106	264	528
Increase/Buy 2005-2011 (42 aircraft)		1,095	2,737	5,474		24,436	61,091	122,182		4,435	11,089	22,177
F/A-18E/F												
Base	27				302				183			
Increase/Unit		3	7	13		30	75	151		18	46	92
Increase/Buy 2005-2011 (190 aircraft)		511	1,278	2,556		5,735	14,339	28,677		3,483	8,707	17,414
F/A-18G												
Base	28				318				193			
Increase/Unit		3	7	14		32	79	159		19	48	96
Increase/Buy 2005-2011 (90 aircraft)		255	637	1,274		2,860	7,149	14,298		1,736	4,340	8,681
F-22A												
Base	140				521				2,547			
Increase/Unit		14	35	70		52	130	260		255	637	1,274
Increase/Buy 2005-2011 (104 aircraft)		1,461	3,651	7,303		5,414	13,536	27,072		26,491	66,227	132,454
F-35 (CTOL)												
Base	3				238				162			
Increase/Unit		0.3	1	2		24	60	119		16	40	81
Increase/Buy 2005-2011 (79 aircraft)		27	68	135		1,881	4,703	9,405		1,279	3,198	6,395
F-35 (CV/VSTOVL)												
Base	5				245				233			
Increase/Unit		0.5	1	2		24	61	122		23	58	116
Increase/Buy 2005-2011 (111 aircraft)		52	129	259		2,719	6,796	13,593		2,583	6,456	12,913

Sources: OUSD(AT&L)/Defense Systems and Industrial Policy

PART VI

CONCLUSIONS

The prices of steel, aluminum, and titanium have risen considerably over the last two years. Lead times of these materials also have increased. Factors such as world economic recovery and the commercial aerospace rebound have influenced metals prices. However, Chinese demand is among the major factors in the rising global demand for steel and aluminum. On the other hand, Chinese demand has a limited impact on the rising global demand for and price of titanium. Due to its rapid development, industrialization, and extraordinary growth over the last several years, China today is the world's largest consumer of both steel (39 percent of world consumption) and aluminum (30 percent of world consumption). Direct Chinese demand for titanium in the world market is small (five percent) but growing. Securing access to the major metals needed to modernize the Chinese economy is an important element in China's overall comprehensive national resource strategy. Indirectly, Chinese marine, airplane, and industrial power generation purchases also are adding to worldwide demand for titanium.

Global steel and aluminum markets are adjusting to increased demand by expanding capacity. Generally, worldwide steel and aluminum production capacity is expected to outpace worldwide demand. The result will be stabilized or declining steel and aluminum prices. Much of the new capacity is being put into place in China. Today, China is the world's largest producer of both steel and aluminum. In fact, China is already a net exporter of aluminum and is becoming a net exporter of steel. As worldwide steel and aluminum production capacity begins to exceed demand, China may have an incentive to maintain its domestic production by reducing its prices, putting pressure on other steel and aluminum producers—including U.S. steel and aluminum producers.

Global titanium demand also is increasing. However, there is limited information available on projected worldwide titanium production or production capacity. It is not clear whether titanium prices are likely to increase, stabilize, or decline.

DoD weapons systems primarily use specialty metals which are produced by the same U.S. suppliers that produce metals for the commercial markets. The Department is a very small consumer of commercial grade metals. However, tight commercial markets could negatively impact the viability of U.S. metals suppliers, and ultimately DoD weapon system programs.

Specialty metals as a percentage of the unit recurring flyaway cost represent a small portion of military aircraft prices. Although additional steel and aluminum price increases appear unlikely, the potential for future titanium price increases remain. Significant future titanium price increases could lead to aircraft price increases for which the Department would have to plan. For example, a 50 percent titanium price increase would increase the unit price of an F-22A by $1,274,000 and the FY05-11 buy (104 aircraft) by $132,454,000. Long-term agreements between prime contractors and metal suppliers could substantially mitigate the impact of unexpected price increases.

Global economic conditions including the effect of rising economies such as China's and India's will be significant factors in the supply, demand, and prices for many commodities. All consumers, including the Department of Defense, will be impacted by these global conditions. Considerations of particular importance for the Department include:

- The Department's smaller share of the market for raw materials lessens its ability to influence the market. Industrial policy levers that attempt to influence supply and demand for defense products are less likely to succeed where the defense demand is a very small percentage of the overall market.
- In a global marketplace it is more difficult to separate defense and commercial needs and trends.

ODUSD(IP) will continue to monitor global economic trends that may impact the Department of Defense.

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