

Guide to NSK Products for Aerospace Applications

NSK products with the performance and reliability
needed by the Aeronautical and Space Industries.



NSK Gives You Higher Performance and Reliability

The NSK group now produces about two billion bearings every year, making it the second largest producer in the world. But NSK's success is based more on quality and innovation than quantity. We have over 80 years of experience in developing new products that are always ahead of their time. The company produces a lot more than just high-precision bearings—research in every field of science has extended our activities to include sophisticated electro-mechanical (mechatronic) products such as robots, IC production equipment, and other advanced systems based on "Motion and Control Technology". NSK has always been a leading supplier of bearings, actuators, and other products for aeronautical and space applications, so you can depend on our expertise for higher performance and reliability.



REALIZING HIGHER PERFORMANCE

Many aerospace products must operate in extremely harsh environments and do it with high reliability. Both high and low temperature extremes, high rotational speeds, heavy loads and shocks, high acceleration, and the vacuum of space are challenging

problems for the designers of such products. With years of experience designing and testing bearing and other products for these and other environmental extremes, NSK has acquired unique technologies to overcome such problems.

1. Ultra-High Precision

Generally speaking, bearing rings and balls are manufactured to be as perfectly round or spherical as anything on this planet. However, the outer rings for jet engine bearings which are used at high speeds and with light loads are occasionally required to be slightly elliptical or triangular. NSK manufactures such bearings using high-precision production and measurement technologies and equipment.



■ Bearing Designed with Elliptical Outer Ring



■ Talyrond Measurement

2. Superior Bearing Materials and Lubricants

High reliability and long life are achieved through the development of the finest materials. NSK works closely with its suppliers to improve the quality and performance of its bearing steels, lubricants, and other materials. Examples of NSK technologies that contribute to longer life include:

- A forging technique that ensures superior grain development parallel to bearing raceways
- High quality ceramics (Si_3N_4) that greatly improve reliability at high speeds
- Special refining technology for steel
- "AP Treatment" that reduces the risk of bearing seizure under adverse operating conditions
- "SHX" steel, a new bearing material that was developed for high temperatures. "SHX" has superior fatigue strength as well as better wear and seizure resistance than conventional bearing materials



■ Bearing Fatigue Testers



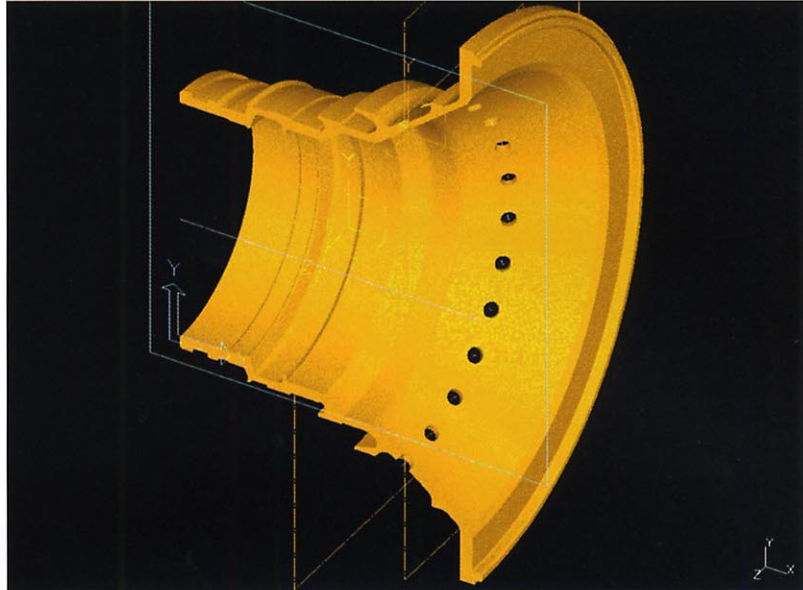
■ Field emission electron probe surface roughness analyzer



■ Scanning Auger microprobe

3. Advanced Stress Analysis

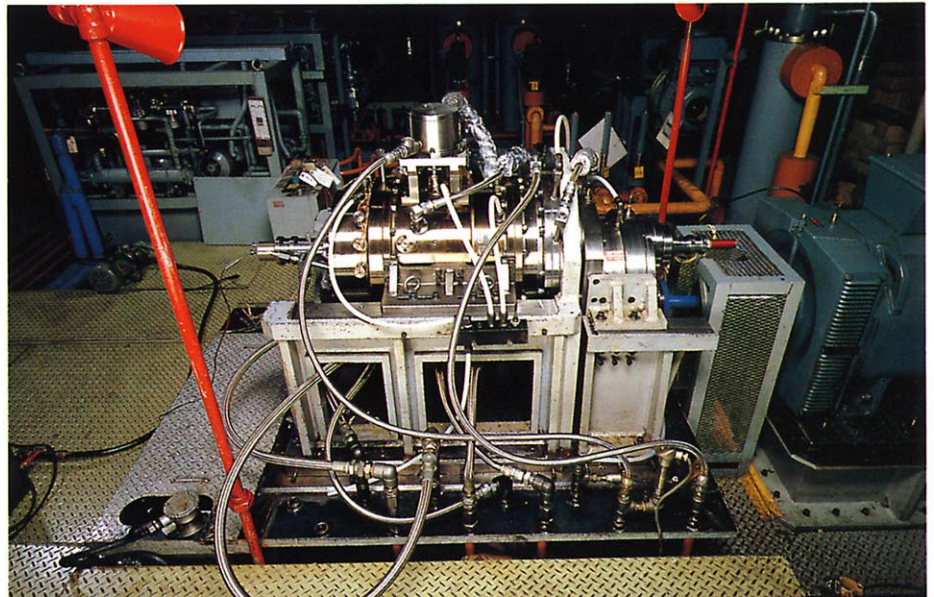
In contrast to most other applications, aircraft and many of their components are inherently flexible structures. For this reason, very detailed and accurate stress and deformation analyses are completed using FEM (Finite Element Method) and BEM (Boundary Element Method). This is essential to determine the effects of structural deformation on bearing loads and life. Such analyses are supported by and correlated with experimental test data to confirm their accuracy.



■ 3D-Model for Stress Analysis

4. Testing under Realistic Operating Conditions

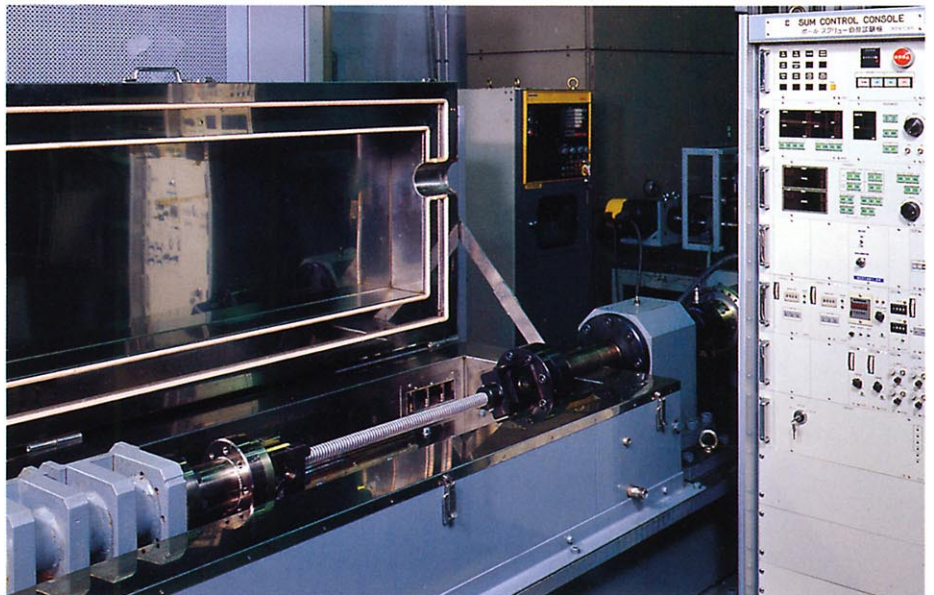
Aircraft engines and components present very severe operating conditions for bearings. Depending on the application, the speed and/or temperature may approach the highest levels that bearings can endure. Other harsh conditions include strong shock loads, extremely high acceleration, and very low temperatures. Naturally, such extreme conditions must be accurately simulated in tests of bearings and other products for aeronautical applications. At NSK and NSK-RHP, the facilities necessary for such tests are in place to meet the diverse requirements of customers around the globe.



■ Test-rig of Jet Engine Bearings

5. Functional and Endurance Test of Ball Screws

Ball screws for aircraft must operate with high reliability under heavy loads and over a wide temperature range (-60°C to 80°C). Long periods of testing are necessary to confirm endurance.



■ Aircraft Ball Screw Test Equipment

REALIZING HIGHER RELIABILITY

Thorough inspections are carried out at every step of production, and processing conditions are monitored and controlled to

ensure maximum consistency. No means of achieving "perfect quality" is neglected.

1. Precise Measurements

The first prerequisite for high quality is precision and that, of course, requires accurate measurements. NSK has the most sensitive instruments available for measuring dimensional accuracy and other physical qualities. At high speeds, precise geometric form is essential for proper balance of rotating parts.



■ Balance Measurement of Roller



■ 3-D Measuring Instrument



■ High Magnification Out-of-Roundness Measuring Instrument (magnification: 200,000)

2. Nondestructive Testing

Bearing parts are inspected at each stage of production from material acceptance to final assembly. This includes nondestructive testing such as inspections utilizing magnetic particles, penetrant dye, eddy currents and X-rays, as well as ultrasonic inspection and NSK's proprietary method of fatigue analysis. NSK also uses ultrasonic inspection technology for the ceramic rolling elements in its aero-engine bearings.



■ X-Ray Metal-Fatigue Test Equipment



■ Eddy Current Inspection

3. Computer-Controlled Production

NSK's sophisticated global computer network, which encompasses marketing, design and manufacturing converts customer-approved drawings into manufacturing drawings, quality-assurance process charts, and working instructions for plant CAD/CAM systems. A complete production history is compiled and stored including process inspection records.



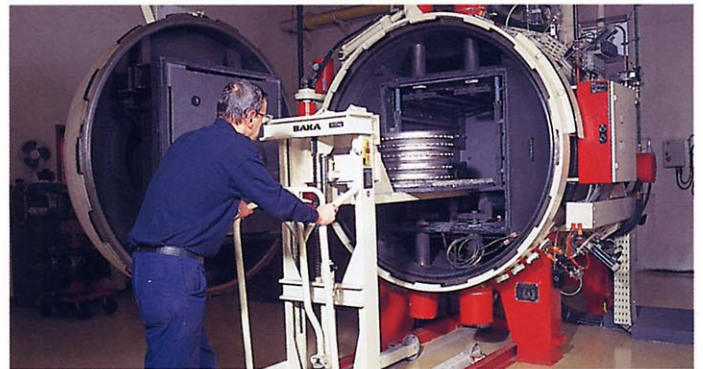
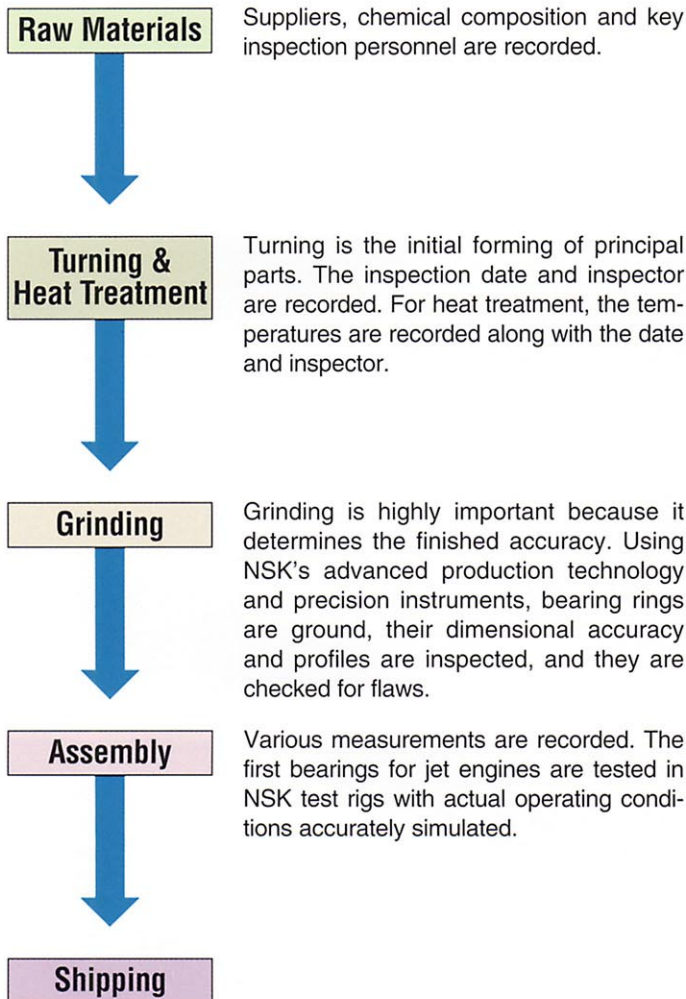
■ Production instructions are sent directly to each shop by computer

4. Traceability of Production

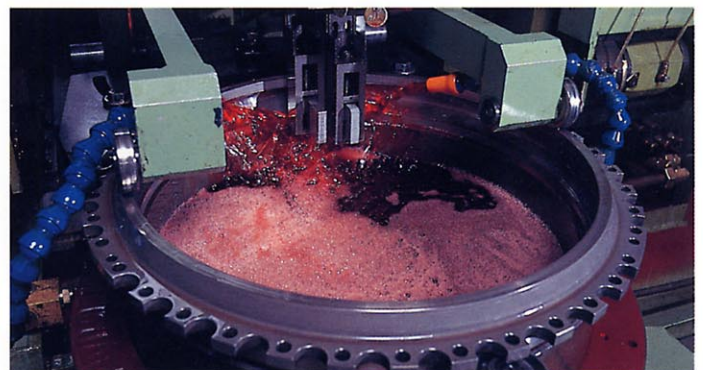
No business has more stringent quality-control requirements than the aerospace industry. NSK bearings, including their individual components, are completely traceable to specific processes,

dates, machines, personnel, instruments, etc. by their serial numbers. Detailed histories of measuring and analysis instruments are also maintained.

Main Processes and Record Control for Aircraft Bearings



■ Heat Treatment



■ Grinding

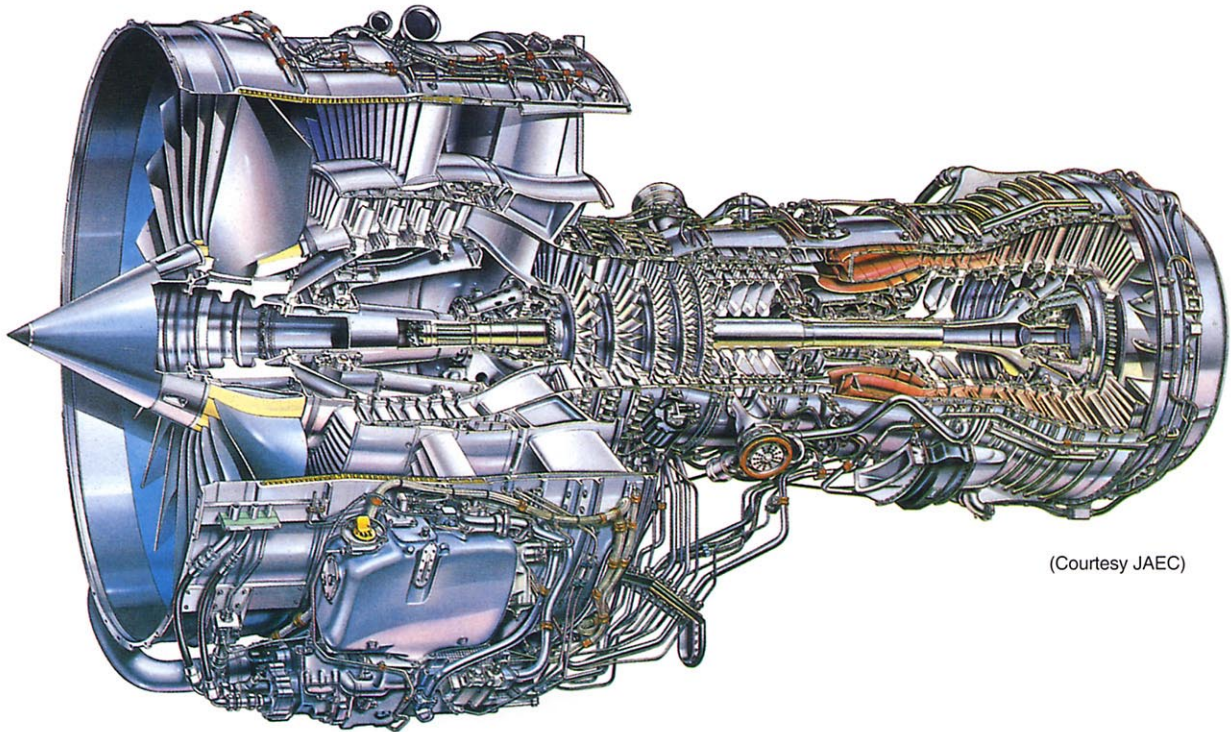


■ Cleanroom for Aircraft Bearing Assembly

Jet Engine Bearings

Bearings designed for use in jet engines are produced with the most stringent quality control. NSK and NSK-RHP have had years of experience in the design, testing, and production of bearings for nearly every jet engine built in Japan. Through this experience, we have developed the technical capability and pro-

duction expertise required to deliver bearings of the highest performance and reliability. NSK was engaged in the design and testing of bearings for the V2500 engine now being manufactured jointly by five countries and manufactures these bearings.

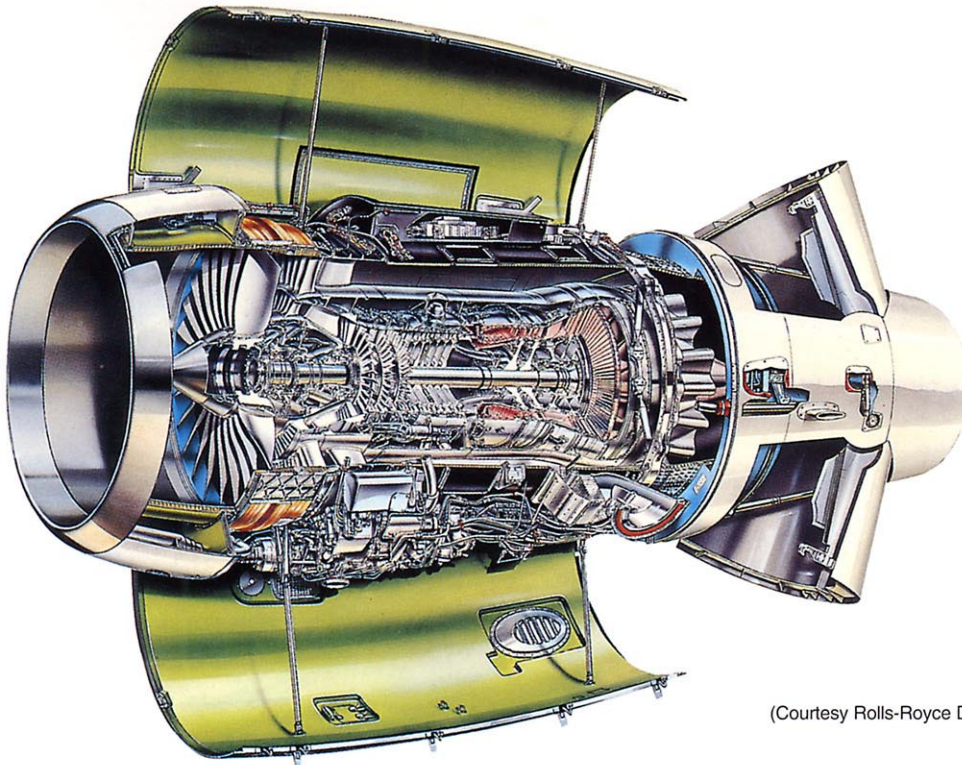


(Courtesy JAEC)



Bearing designs are often required to have integrated components such as flanges, squirrel cages, gears and stub-shafts. As a result, design work becomes more complicated and the analysis of bearing structural behavior, material selection and production method engineering must be carried out in greater detail.

NSK-RHP has manufactured and supplied five mainshaft bearings including both ball and roller bearings for the BR710 and 715 engines. These engines are among the most advanced turbofan engines used to power regional aircraft.

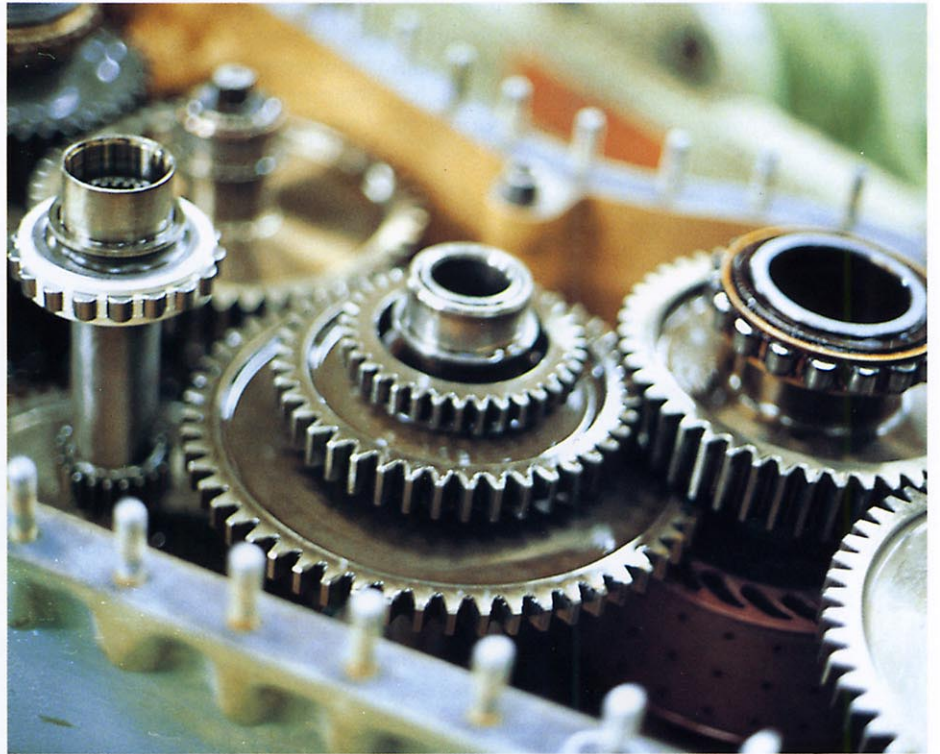
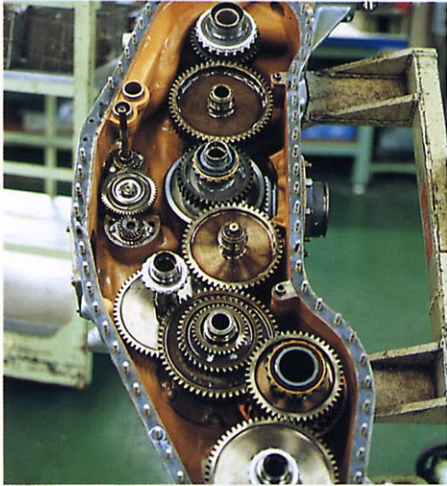


(Courtesy Rolls-Royce Deutschland G.m.b.H)



Gearbox Bearings

Bearings for gearboxes in aircraft must sustain heavy loads and, at the same time, be small and light. NSK engineers are studying ways to reduce weight including the use of new materials like ceramics.



Bearings for Aerospace Instruments and Controls

Numerous miniature bearings are required in the instruments, controls and other auxiliary equipment in aircraft and space vehicles. Examples include gyroscope rotors and gimbals, servomotors, micromotors and fuel supply equipment. Because of the critical nature of these applications, their bearings are produced under strictly controlled conditions to ensure maximum cleanliness, precision and reliability.



Gyroscope Bearings

The gimbals in gyroscopes oscillate very slowly, making them very sensitive to the starting torque of their bearings. For this reason, NSK conducted a great deal of research into reducing torque through the use of unique materials (e.g., sapphire and carbide) and special designs. The result was a low torque of $0.3 \text{ N}\cdot\text{mm}$, a level previously considered difficult to achieve. Unlike gimbal bearings, gyroscope rotor bearings run at very high speed and their bearings must perform without any irregularity for long periods.



Airframe Bearings

Landing Gear Bearings

Landing gear must sustain heavy loads, severe shocks, and extremely high acceleration during landing. Specially designed tapered roller bearings made of carefully selected materials are used for this application.



Control Bearings

Many deep groove ball bearings that are sealed and have spherical aligning seats are used on control rods in aircraft. They must sustain heavy loads and be capable of operating in harsh conditions like extremely high and low temperatures. They have spherical seats to compensate for the bending of the rods, special seals and lubricant for the extreme operating temperatures, and special surface treatments to improve corrosion resistance.



Needle Roller Bearings

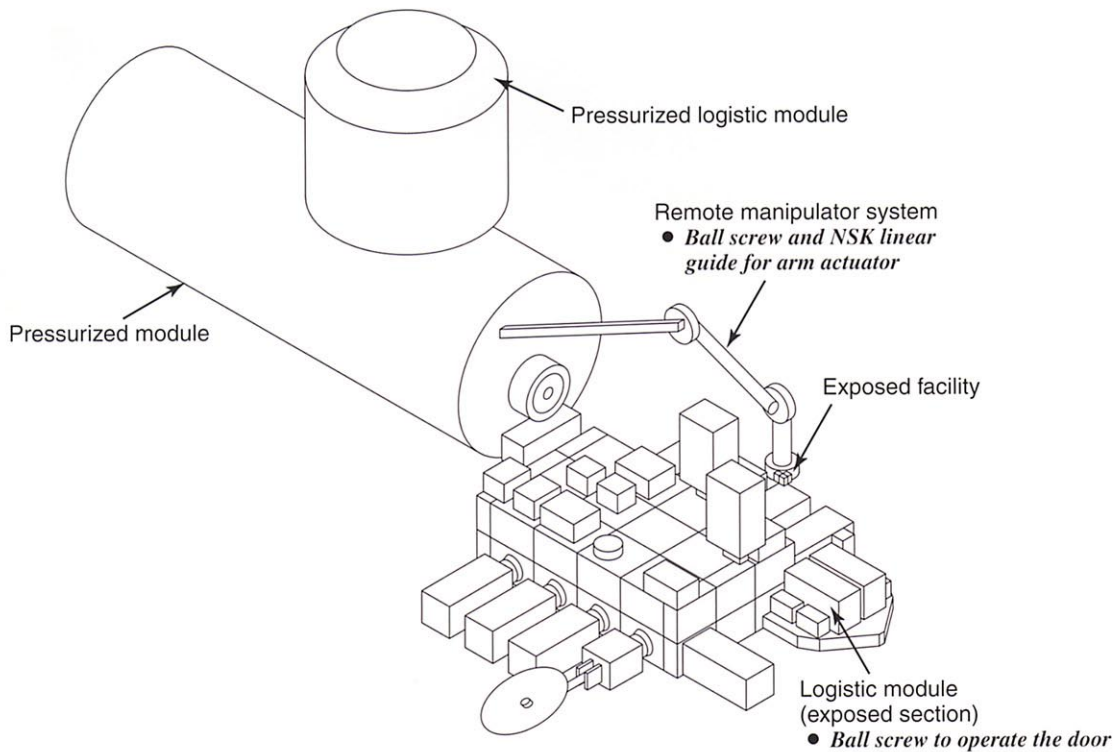
Many needle roller bearings are used in aircraft because they offer maximum load capacity for their small size and weight. They have been standardized to conform to MIL specifications. Highly specialized needle bearings were developed for the vanes and other positions in afterburners. Other special designs have been developed for use in engines, flaps, slats and other areas.

Linear Motion Products (Ball Screws and NSK Linear Guides)

Besides the anti-friction bearings, NSK is a leading manufacturer of linear motion products such as precision ball screws and linear guides. The adoption of these products in the aerospace applications are steadily increasing. They are now used for manipulator, open and shut mechanism for door of logistic module of the space station, jet engine nozzle control and flap and slat actuators for aircraft. Since their operating conditions are often severe, NSK has developed techniques for improved metallurgy, surface treatment and inspection. NSK will strive after the innovative solutions for the hostile environment in the space and will adopt its results for better linear motion products.



NSK linear guides and ball screws for space station



■ Ball Screws for Aircraft Actuator Applications

Examples of Ball screw Applications

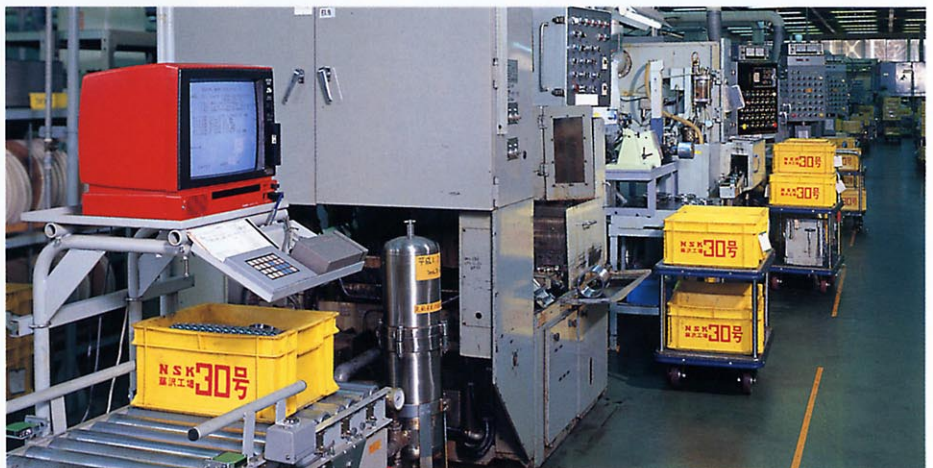
| Classification | Application |
|----------------|--|
| Space | <ul style="list-style-type: none"> ● Ball screw for rocket engine jet control ● NSK linear guides and ball screw for docking mechanism of an experimental satellite ● Open and shut mechanism of the door for logistic module (JEM) ● NSK linear guides and ball screws for arm actuators of remote manipulator system (JEM) |
| Aircraft | <ul style="list-style-type: none"> ● Ball screw for flap actuator ● Ball screw for stabilizer trim control ● Ball screw for jet engine nozzle control |
| Others | <ul style="list-style-type: none"> ● Ball screw for missile control actuator ● Ball screw for flight simulator |

CUSTOMER SERVICE

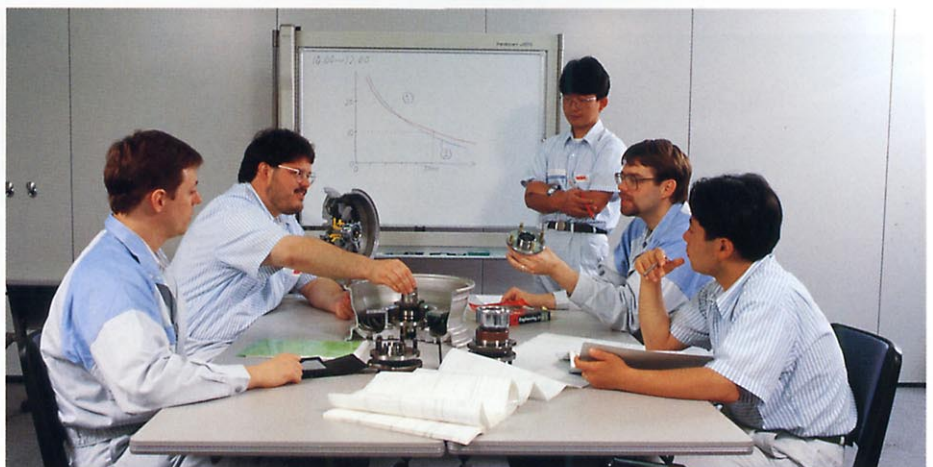


■ NSK Head Office

NSK has a worldwide communication network with a huge database containing information about all of its products. This extensive system has CAD capabilities that enable customers to present their requirements and receive technical assistance almost immediately, including selection of the optimum bearing or ball screw, its specifications and availability. Please contact any NSK or NSK-RHP sales office or representative for further information.



■ Computer Aided Production Line



■ Technical Assistance

