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ROTORCRAFT TRANSMISSIONS

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ABSTRACT

The NASA Lewis Research Center and the U.S. Army Aviation Systems Command share an interest in advancing the technology for helicopter propulsion systems. In particular, this presentation outlines that portion of the program that applies to the drive train and its various mechanical components. The major goals of the program are to increase the life, reliability, and maintainability; reduce the weight, noise, and vibration; and maintain the relatively high mechanical efficiency of the gear train. The current activity emphasizes noise reduction technology and analytical code development followed by experimental verification. Selected significant advances in technology for transmissions are reviewed, including advanced configurations and new analytical tools. Finally, the plan for transmission research in the future is presented.

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TRANSMISSIONS TECHNOLOGY REQUIRED FOR 1990's

The major goals of the program are to increase the power-to-weight ratio, increase the reliability, and reduce the noise.

TRANSMISSIONS
TECHNOLOGY REQUIRED FOR 1990's

REQUIREMENT	GOAL	BENEFIT
LIGHTER STRONGER	DRIVE TRAIN SPECIFIC WEIGHT 0.3 TO 0.5 lb/hp (CURRENTLY 0.4 TO 0.6 lb/hp)	INCREASED RANGE AND PAYLOAD
MORE RELIABLE	5000-hr MEAN TIME BETWEEN OVERHAULS (MTBO) (CURRENTLY 500 TO 2000 hrs)	LOWER OPERATING COST AND SAFER OPERATION
QUIETER	70 TO 80 dB IN CABIN (CURRENTLY 100 TO 110 dB)	GREATER USE FOR COMMERCIAL COMMUTER SERVICE INCREASED PASSENGER AND PILOT COMFORT

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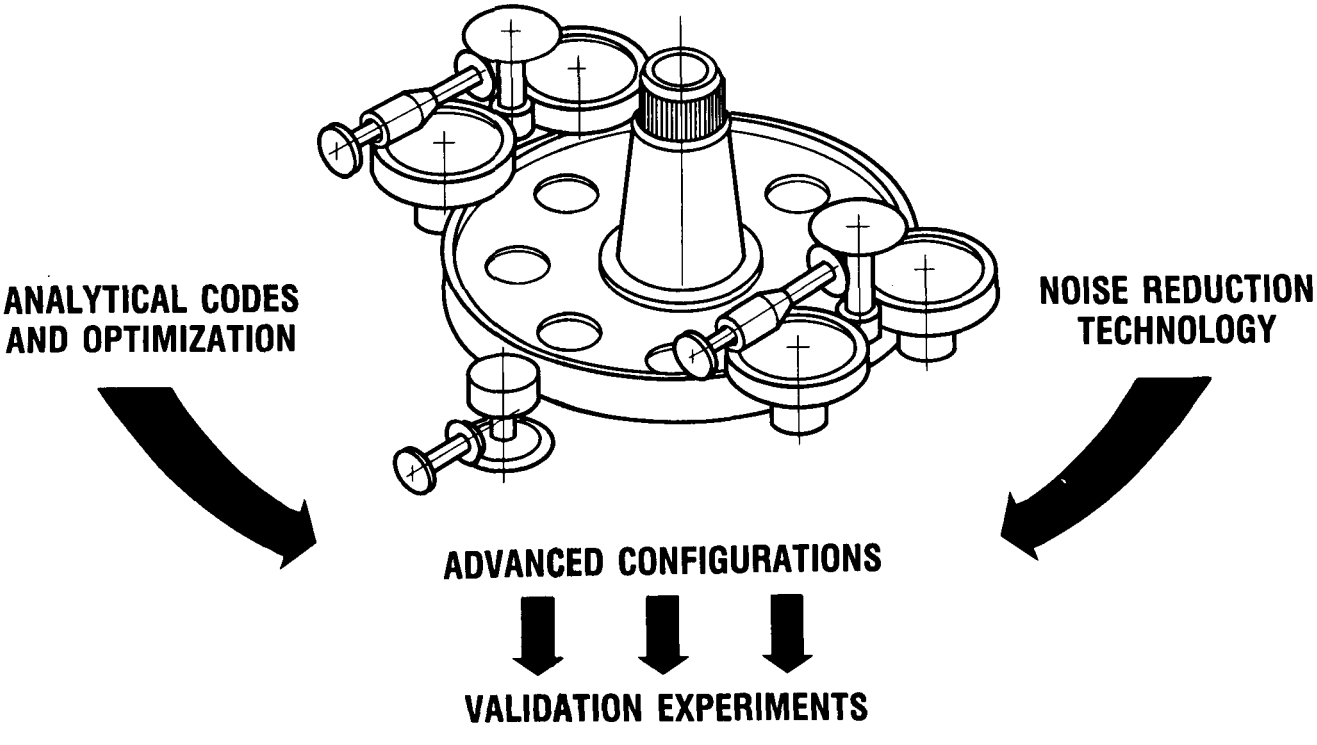
CURRENT RESEARCH ACTIVITY IN TRANSMISSIONS

The current activity emphasizes analytical code development and validation, with emphasis on noise reduction technology for drive systems.

Based on the experimental, analytical, and design studies conducted under the transmission technology program, some advanced transmission concepts were evolved, including the advanced 500-hp transmission, the bearingless planetary transmission, and the split-torque transmission.

An extensive data base has been established for two sizes of helicopter transmissions.

CURRENT RESEARCH ACTIVITY IN TRANSMISSIONS



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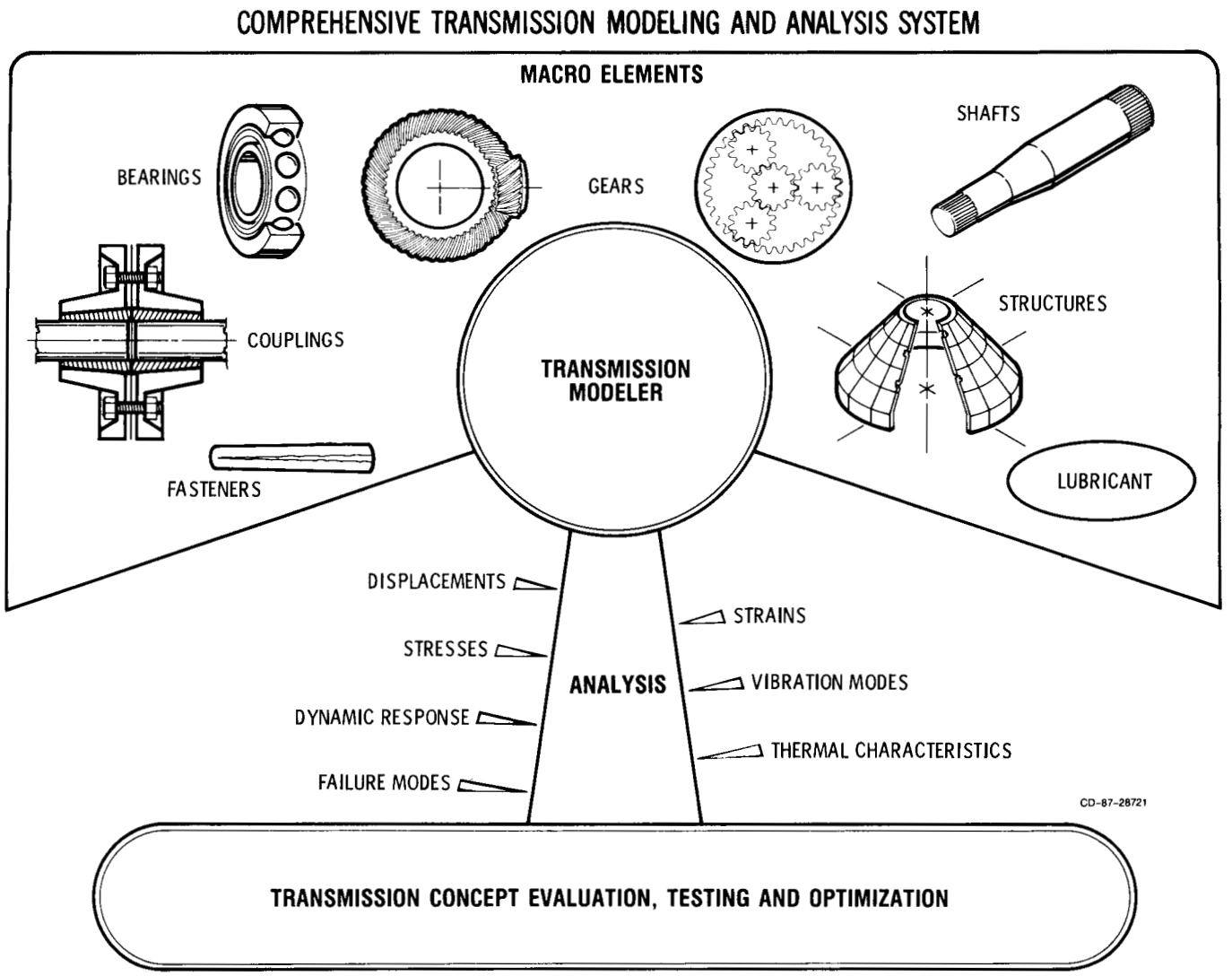
COMPREHENSIVE TRANSMISSION MODELING AND ANALYSIS SYSTEM

An in-house and university grant effort continues to develop computer programs for analysis and design of transmission systems. The unique facilities and hardware at Lewis are being used to validate the computer codes and to collect additional data for use in developing the codes. A library of computer codes and subroutines for transmission system analysis is being assembled. The goal is to develop a comprehensive computer program library for transmission system modeling.



HELICOPTER TRANSMISSION LIFE AND RELIABILITY COMPUTER PROGRAM

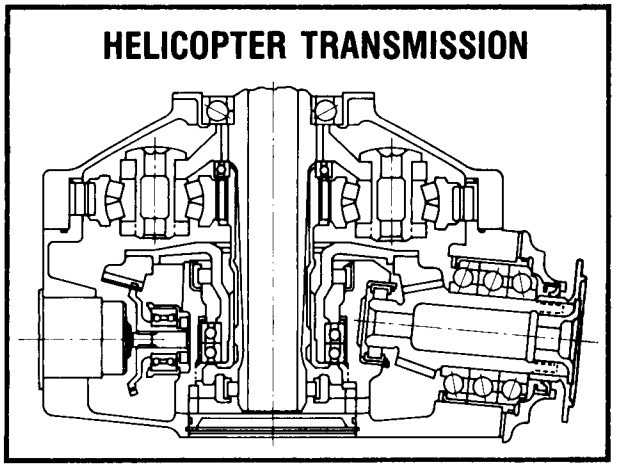
Drive system life and reliability are important issues during the design, development, and field operation of helicopters. Analytical tools are needed for design and for comparing competing and alternate designs.

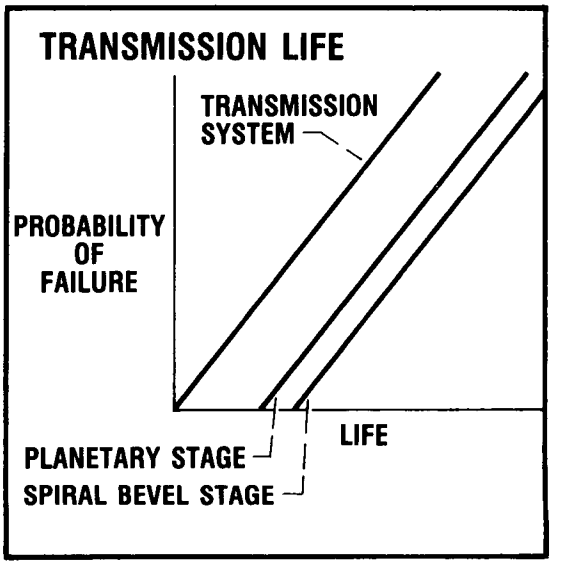
To meet this need, a versatile computer program was developed to predict helicopter transmission life. The program predicts mean time between failures (MTBF) and can be used to evaluate proposed new designs and to project spare parts requirements for helicopter fleet operations.

HELICOPTER TRANSMISSION LIFE AND RELIABILITY COMPUTER PROGRAM

SIGNIFICANCE:

- **VERSATILE COMPUTER PROGRAM FOR PREDICTING TRANSMISSION LIFE AND RELIABILITY**
- **TOOL FOR EVALUATING PRELIMINARY AND COMPETING DESIGNS**
- **PROVIDES INFORMATION THAT CAN BE USED TO PLAN SPARE PARTS REQUIRED**





FEATURES:

- **INPUTS: TRANSMISSION CONFIGURATION, LOAD, AND SPEED**
- **OUTPUTS: TRANSMISSION COMPONENTS AND SYSTEM LIVES**

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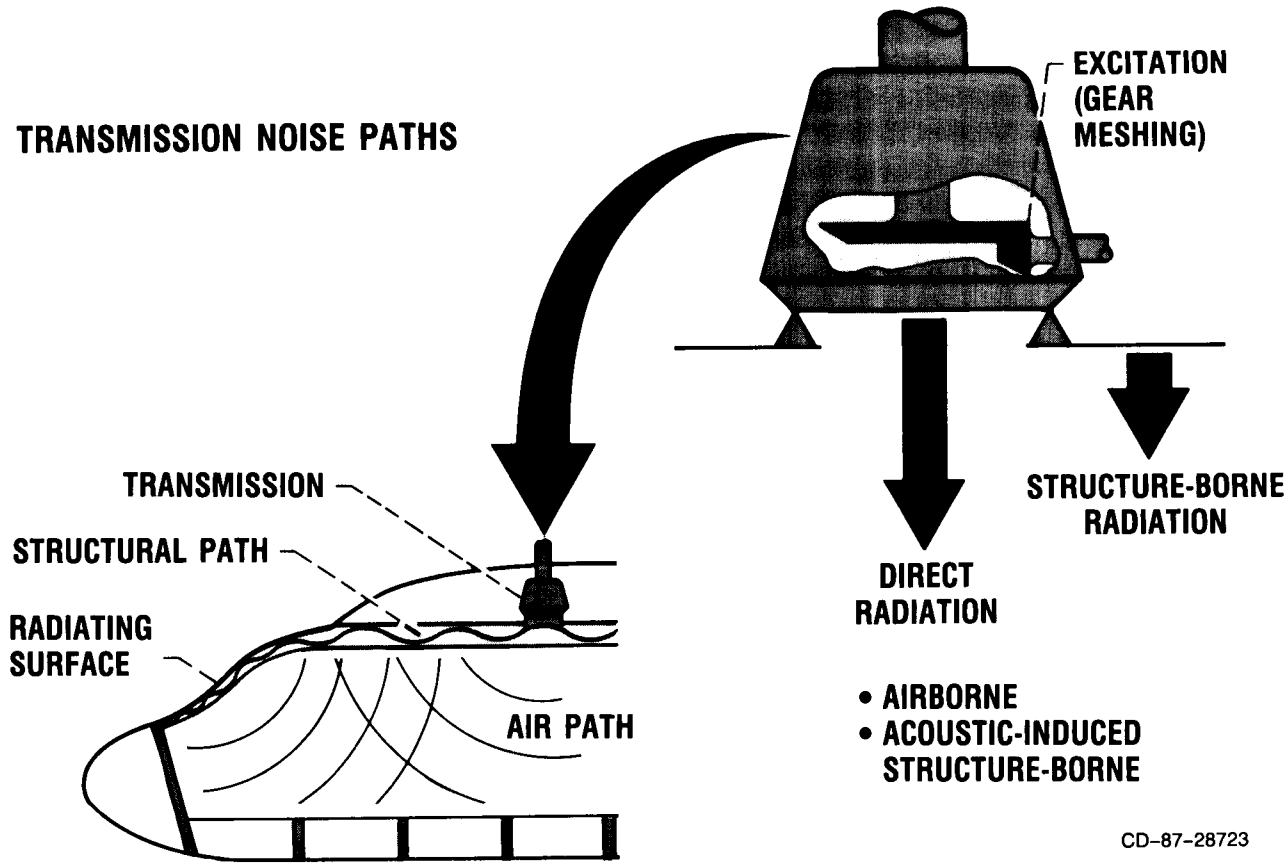
TRANSMISSION NOISE REDUCTION TECHNOLOGY FOR ROTORCRAFT

Historically, helicopters have been plagued by internal noise problems. The transmission is a particularly troublesome source and is believed to be the main source of annoying noise in the helicopter cabin. The noise from the transmission enters the cabin by two paths, structure-borne radiation and direct radiation.

The major portion of our program in transmissions is devoted to finding solutions to this problem.

TRANSMISSION NOISE REDUCTION TECHNOLOGY FOR ROTORCRAFT



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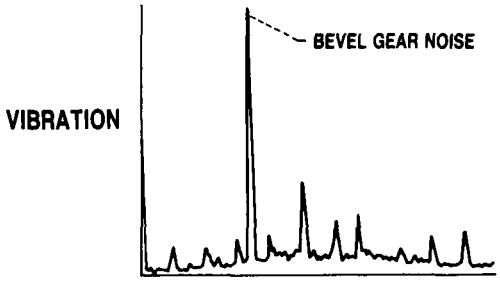
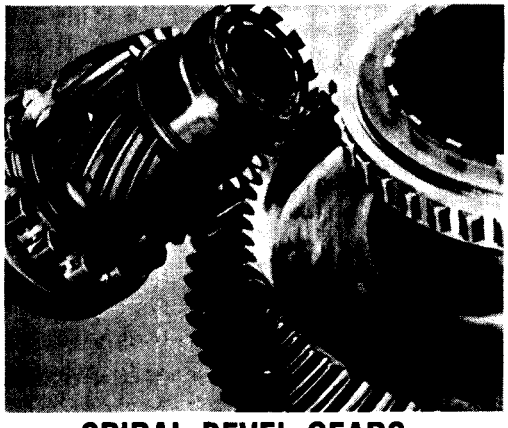
Spiral bevel gears are used in helicopters to transmit power "around the corner" from a horizontal engine output shaft to the vertical rotor shaft. Vibration from spiral bevel gears is a strong source of transmission noise.

The goal of a recent study was to relate gear noise to dimensional and physical factors of the gears. The work completed (1) provides the first detailed mathematical understanding of generalized transmission error in spiral bevel gears, (2) allows prediction of vibration excitation based on gear tooth measurements, and (3) relates gear noise to physical design parameters and therefore provides a basis for future improvements in spiral bevel gear design.

SPIRAL BEVEL GEAR NOISE MODELING





SPIRAL BEVEL GEARS

MILESTONES COMPLETED:

- MATHEMATICAL MODEL OF ZONE OF TOOTH CONTACT FOR SPIRAL BEVEL GEARS
- NEW UNDERSTANDING OF THREE-DIMENSIONAL NATURE OF TOOTH MESHING
- TIME AND FREQUENCY DOMAIN ANALYSIS FOR NOISE EXCITATION FUNCTION
- NASA CR 4081

SIGNIFICANCE:

- ALLOWS PREDICTION OF VIBRATION FROM GEAR MEASUREMENTS
- PROVIDES BASIS FOR FUTURE IMPROVEMENTS IN SPIRAL BEVEL GEAR DESIGN

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ADVANCED TRANSMISSIONS

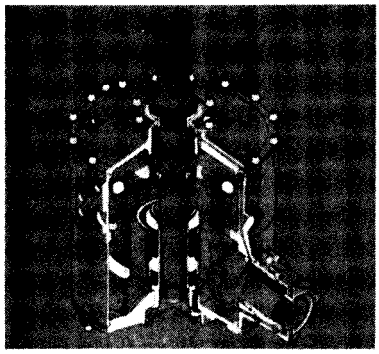
This chart shows some of the advanced transmissions and concepts that are being studied.

The fundamental concept of the split-torque design is that the power from the engine is divided into two parallel paths prior to recombination on a single gear that drives the output shaft. Studies have shown that replacement of the planetary gear reduction stage with a split torque results in weight savings and increased reliability. The advantage of the split-torque transmission over the planetary transmission is greatest for the larger sized helicopters.

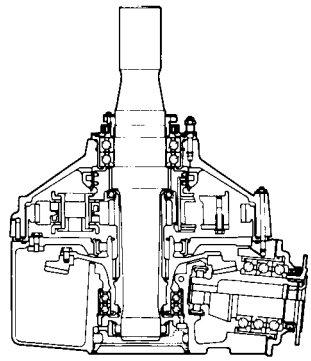
The improved 500-hp design has a weight-to-horsepower ratio of 0.26 lb/hp, compared to 0.37 lb/hp for the 317-hp OH-58C transmission. This transmission is the basis for the transmission in the Army's improved OH-58D model helicopter.

The self-aligning, bearingless planetary (SABP) transmission utilizes a sun gear, planet spindle assemblies, ring gears, and rolling rings. This design projects a weight savings of 17 to 30 percent and a reliability improvement factor of 2:1 over the standard transmission.

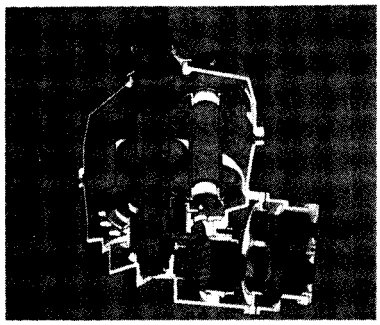
ADVANCED TRANSMISSIONS



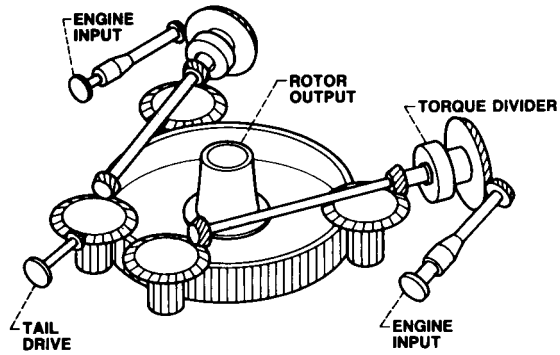
500-hp BEARINGLESS PLANETARY (LOW-RATIO)



500-hp/ADVANCED COMPONENTS



500-hp BEARINGLESS PLANETARY (HIGH-RATIO)



3600-hp SPLIT TORQUE

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FUTURE THRUST

The plan for future NASA/Army transmission research calls for increased emphasis on noise reduction, an aggressive development of computer-aided design codes for transmissions, and the design and construction of demonstrator transmissions in large and small size categories.