Southwest Research Institute Helicopter Test Stand Capabilities

SOUTHWEST RESEARCH INSTITUTE®
SAN ANTONIO, TX ● HOUSTON, TX ● ANN ARBOR, MI ● WASHINGTON, DC

Most helicopter depots must work on a mix of helicopters produced by different manufactures such as Bell, Sikorsky, Boeing and Eurocopter. The logistics of maintaining and testing different helicopter transmissions produced by different companies represents a significant technical challenge. SwRI has been involved with helicopter transmission test stands and test facilities and can provide solutions to test stand problems along with providing leading edge technology to advance the current capabilities of most repair depots.

SwRI is located in San Antonio, Texas and sits on an 1100 acre site. On this site there are over 200 buildings occupying 2,000,000 square feet of laboratory and office space. SwRI operates over 240 dynamometers at its facility and has conducted over 32,000,000 hours of testing over the past 60 years. SwRI employs 3300 employees of which 800 are engineers and 1100 are technicians. The SwRI facility is shown in the figure below.

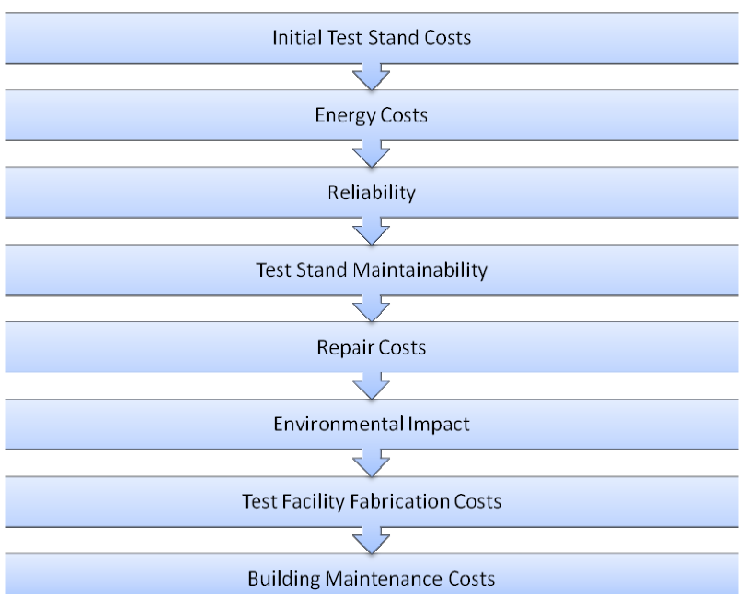
Southwest Research Institute fabricates various types of test stands depending on the needs of the user. SwRI has been involved in extensive studies and designs for such transmissions used in the following seven helicopters:

Apache
Blackhawk
Chinook
Huey
Cobra
Kiowa
Heavy Lift CH-35K

In the case of helicopter gearboxes which typically have multiple inputs and multiple outputs there are three different types of test stand configurations that can be provided and they are:

Non regenerative
Mechanically regenerative
Electrically regenerative

Some of the primary factors that affect which configuration is optimal for a particular application include initial costs, total lifetime costs, number of transmission to be tested per year, number of different transmission models to be tested and facility related capabilities/limitations. Other factors are shown below.



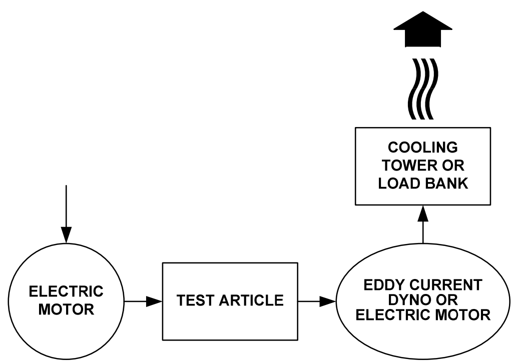
In each of the above categories, SwRI has developed extensive models for component costs, reliability, power usage during testing, MTBF predictions, maintenance tasks and representative estimated component repairs.

TYPE OF HELICOPTER TEST STANDS

A brief overview of the three different helicopter test stand types is provided in the following paragraphs.

Non-Regenerative–Electrical

The non-regenerative electrical system consists of an electrical motor at the input that is used to rotate or power the test article. The test article is loaded by either an eddy current dynamometer or an electrical generator. In this type of system, the absorbing energy is dissipated in some form of heated fluid routed to a cooling tower or electrically to a resistance load bank and no energy is recovered.

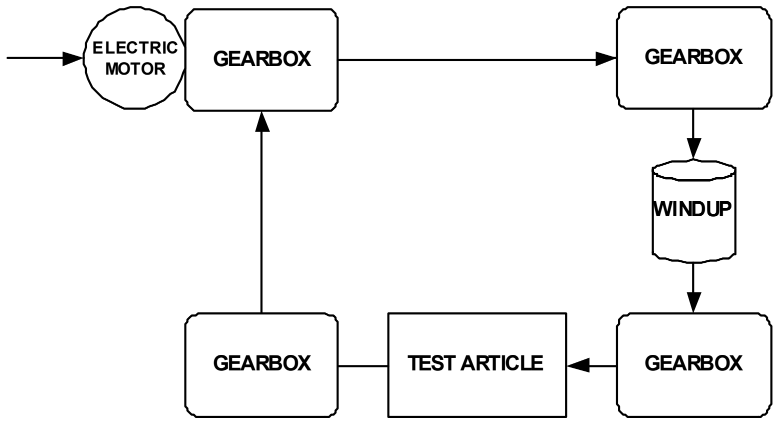


Non-Regenerative Electrical System

Mechanically Regenerative

This type of configuration is often referred to as a '<u>four square.</u>' The four square refers to the four gearboxes or corners that are mechanically tied together to create a square with all gearboxes operating simultaneously to create a closed system. Included within the square is a test article. The system is operated by a single electric motor at one gearbox or corner. The system, as described above, will only rotate the test article in an <u>unloaded or spin</u>

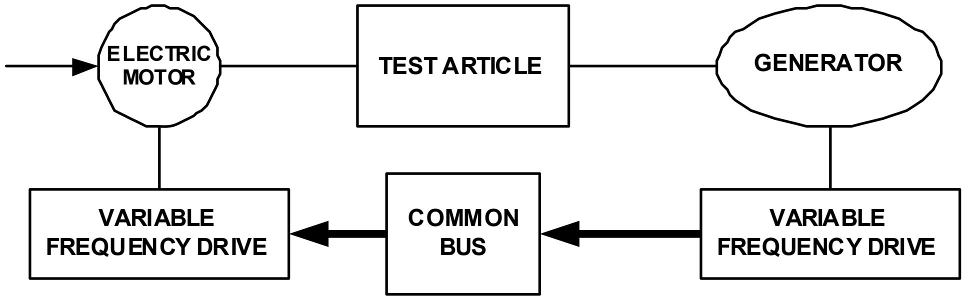
condition. **To load** the test article, a torque is introduced into the closed system and subsequently maintained with a preload or windup device. In a mechanically regenerative system, the electric motor is relatively small, as it needs to be sized only to <u>overcome the parasitic mechanical losses.</u>



Regenerative Mechanical System

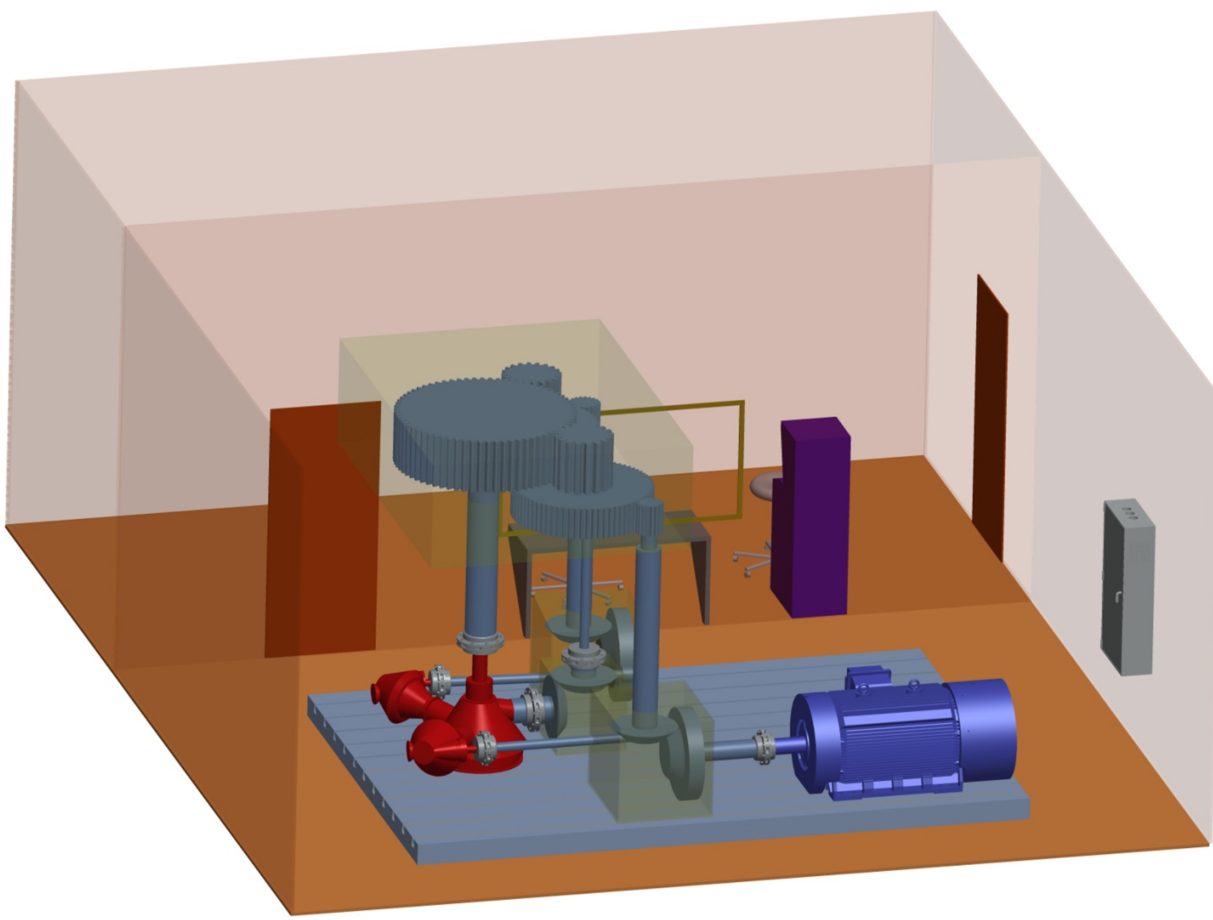
<u>Electrically Regenerative</u>

An electrically regenerative system is similar to the mechanically regenerative system in that it has four corners. However, these four corners use electric motors, generators, and variable frequency drives to complete the square. Two of these corners are **<u>connected mechanically</u>**, and two are **<u>connected electrically</u>**. The electric motor mechanically drives the test article which in turn is mechanically connected to a generator that loads the test article. Input power to the electric motor is provided and controlled by a motoring variable frequency drive. Output power and torque absorbed the generator is controlled and converted to usable electrical energy using an electrically regenerative variable frequency drive. The two variable frequency drives are connected via a common Direct Current (DC) bus which electrically recirculates power, such that the total power input required from the external electrical grid to operate the system needs only to overcome the electrical parasitic losses associated with the motors and generators, and the mechanical losses associated with the unit under test.

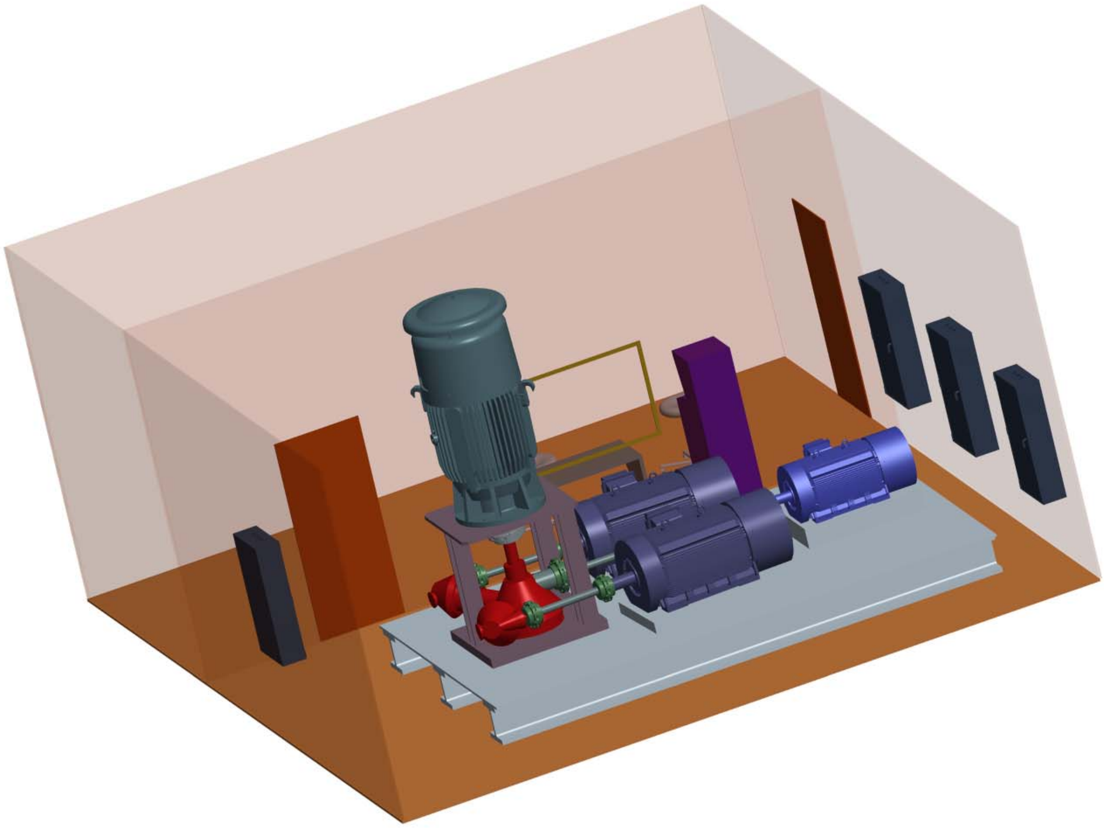


Regenerative Electrical System

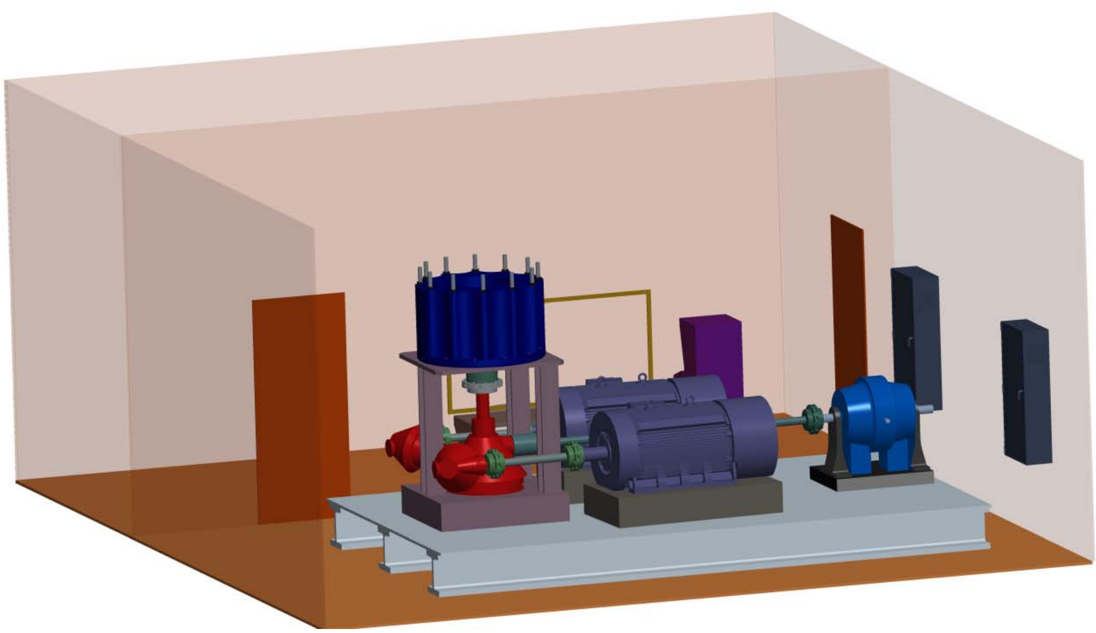
Representative models of these three types of test stands are shown below:



<u>Mechanically Regenerative</u>

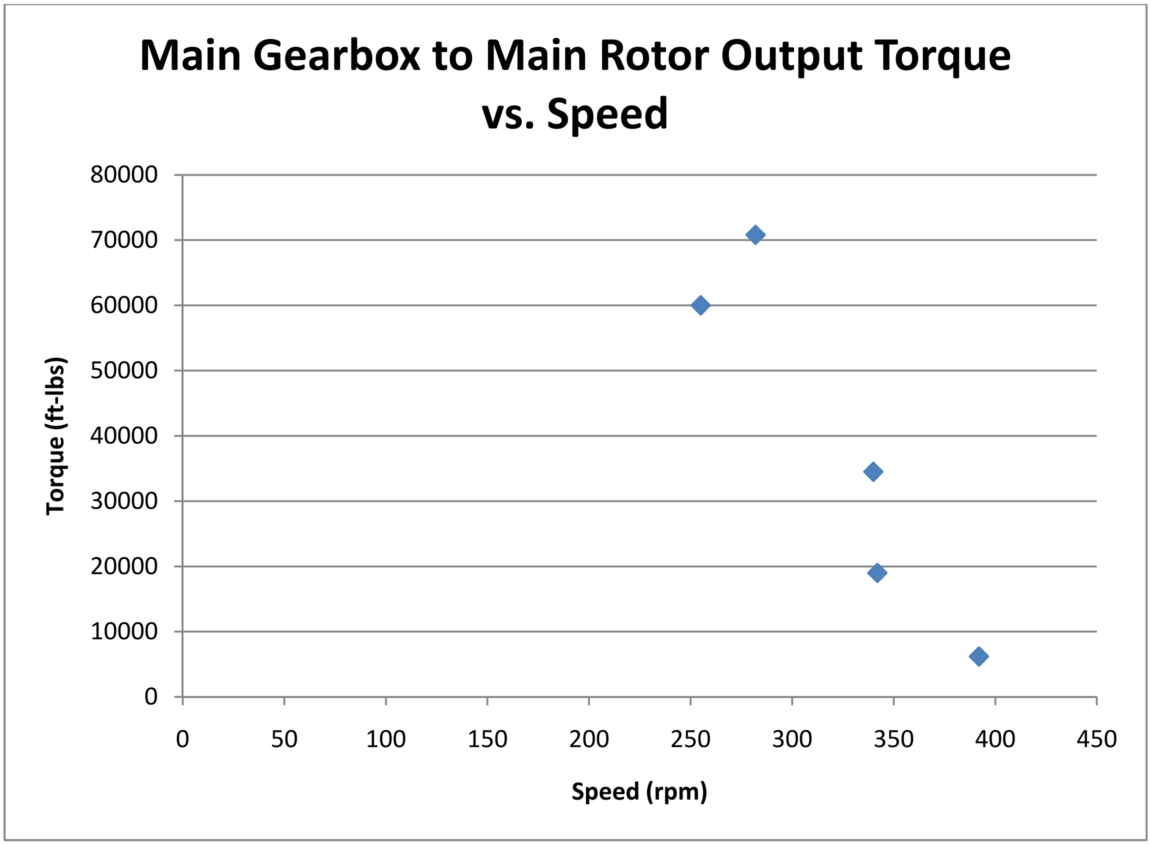


Electrically Regenerative

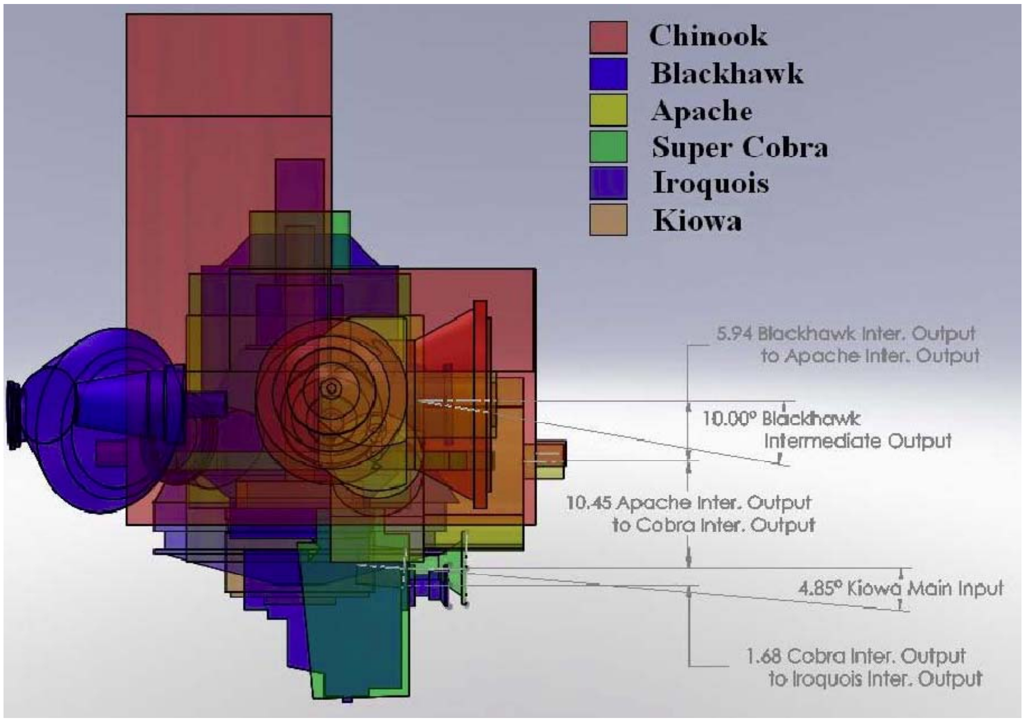


Non-Regenerative

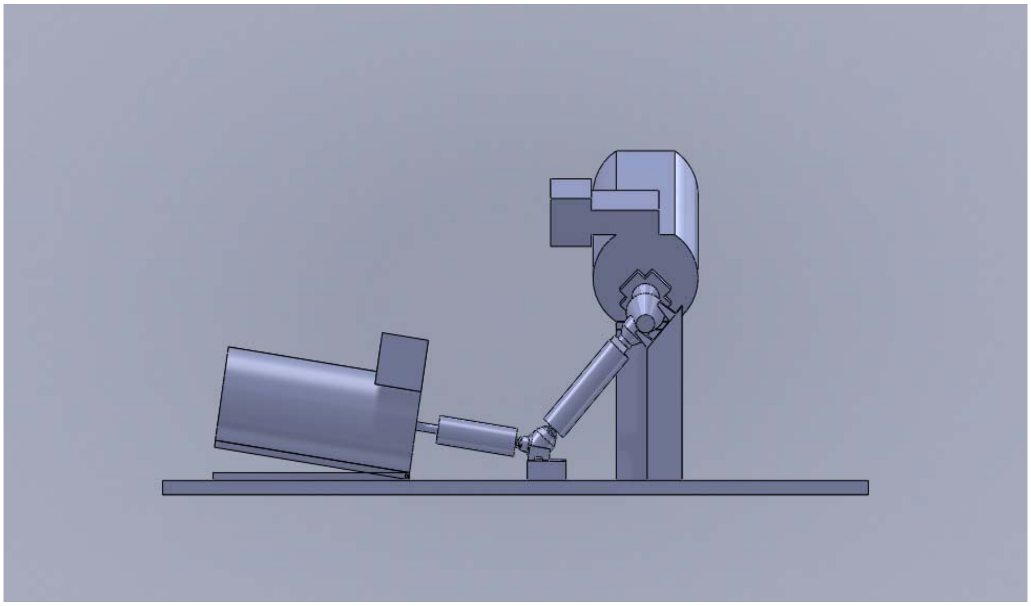
In many depot's transmissions used on different helicopter models are tested. SwRI has addressed these needs in the past. For a test stand to accommodate multiple transmission models it must meet the dual requirements of different torque speed conditions and input/output positions. For example the torque-speed requirements typically have a wide dynamic range, such as shown in the figure below for the output from five different transmissions. This is satisfied by the selection of a non standard motor/dynamometer or by shaping the torque speed curve by using speed reducing gearboxes.



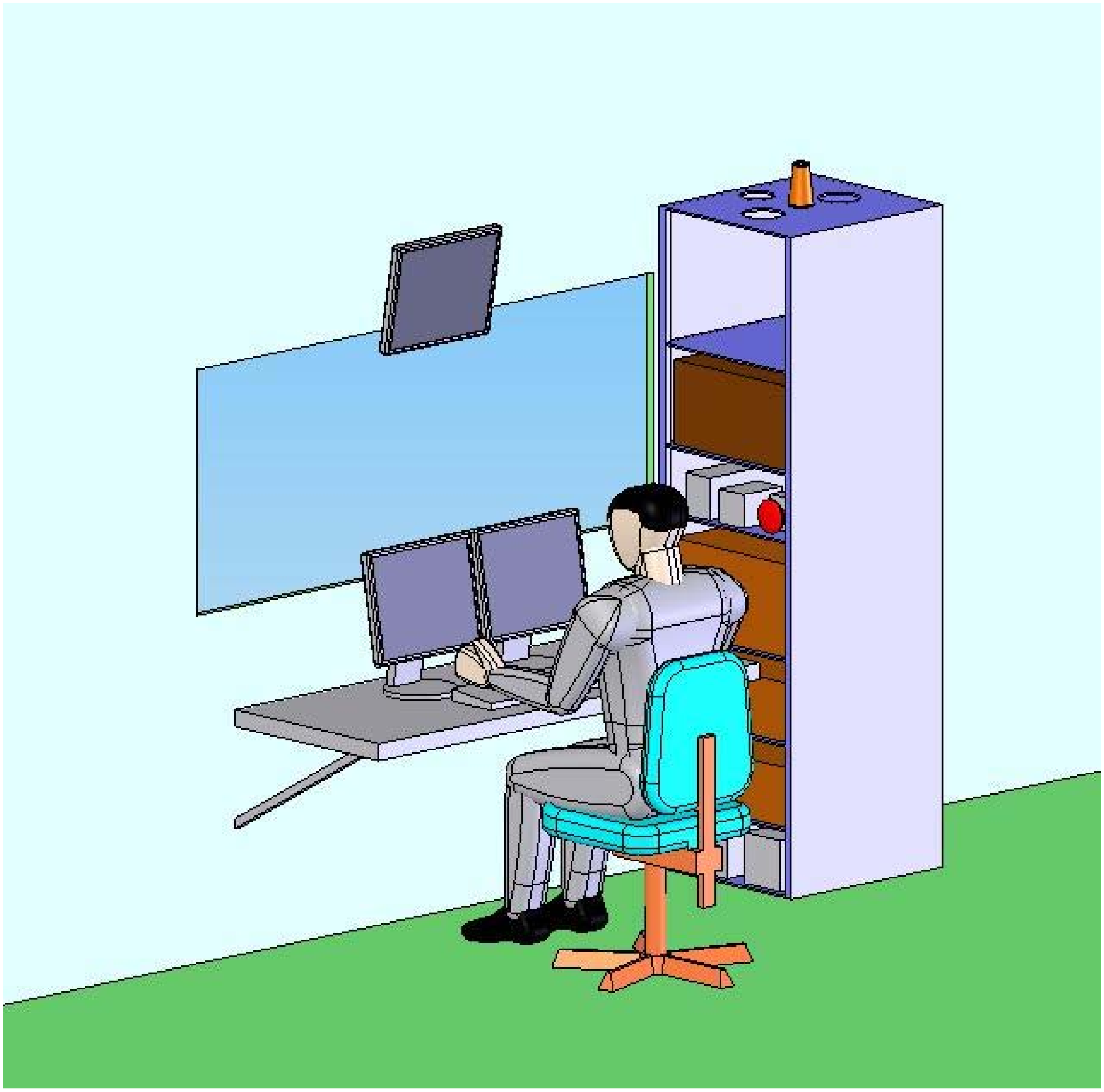
In a similar sense input/output shaft positions and angles vary dramatically as seen in the figure below. The differences are accommodated by using ballscrew operated adjustable position tilt tables.



Nose and intermediate or tail gearboxes all have the same issues but are much easier to deal with using a flexible test stand as shown below.



Typical transmission test stands are configured with 50-75 sensors for temperature, pressure, torque, speed, flow, acceleration and chip detection.

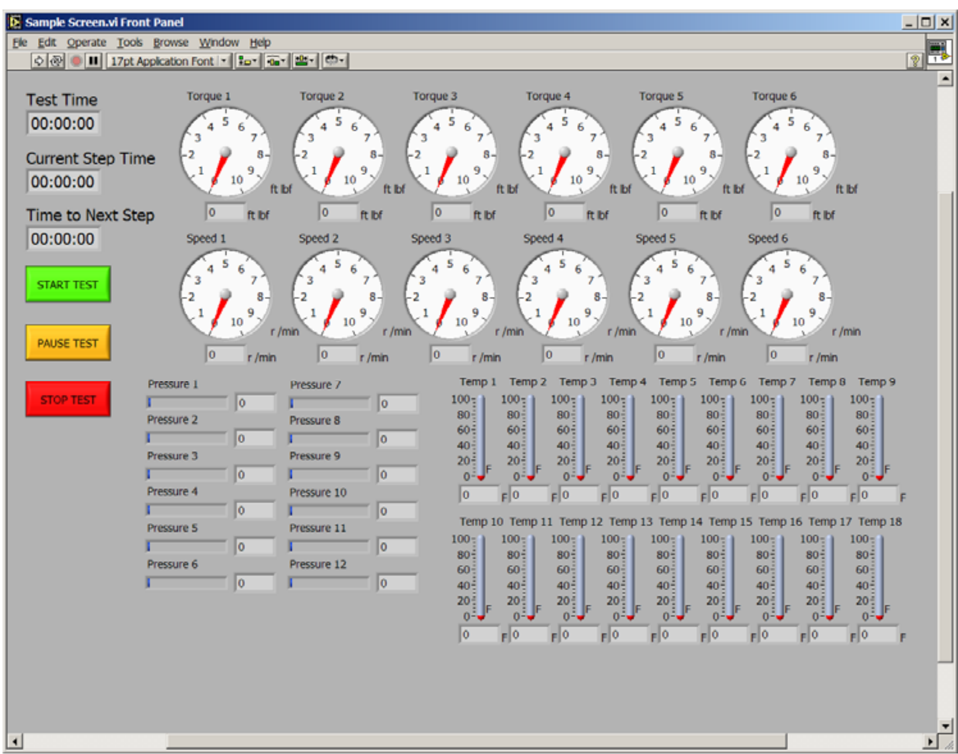


Integrating all of the functions of the test stand is the data acquisition and control system. SwRI typically uses a suite of personal computers (PC's), programmable logic controllers (PLC's) and data acquisition system hardware (DAS). Typically, National Instruments data acquisition hardware and Rockwell PLC's are used. The data acquisition software typically used is LabView and Profibus for the ladder logic in the PLC's.

The grouping of just some of the major functional capability categories that the software provides is as follows:

- Motor Control
- Torque Control
- Temperature Control
- Test Stand Setup
- Calibration
- Manual Operation
- Automated Operation
- Test Pause/Resume
- Alert Level Monitoring
- Flight Data Recorder
- Safe E-Stop
- Emergency Stop

These functions are presented to the operator using a Graphical User Interface (GUI) as shown in the figure below

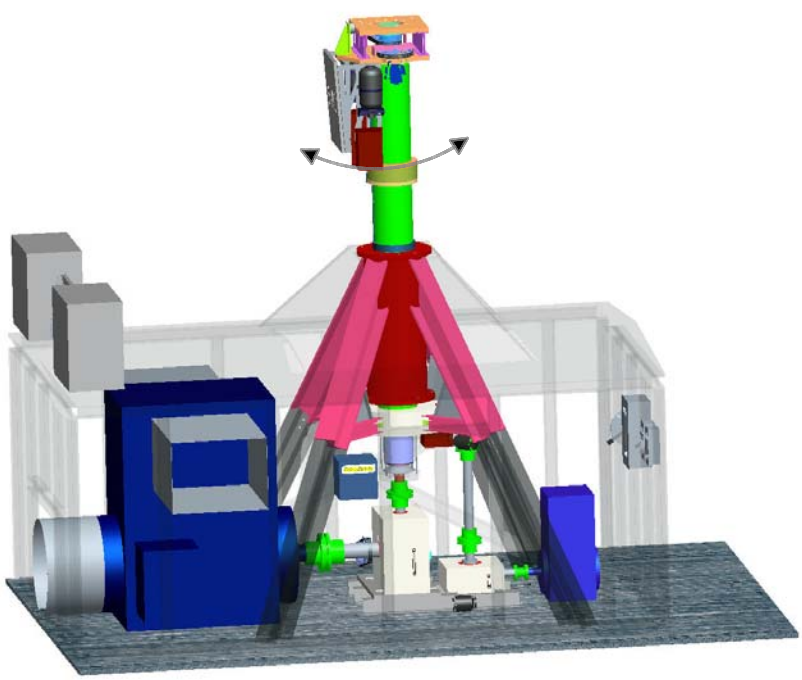


TAIL ROTOR WHIRL STANDS

A certain manufacturer required a new test stand capable of testing tail rotor gearboxes. A challenging characteristic associated with this test stand was its space and performance requirements. Some of these included having a high speed main rotating shaft operate within a concentrically positioned slower precession shaft assembly, meeting predefined-helicopter equivalent torsional and lateral natural frequencies; and torsional stiffness and inertia values. SwRI performed torsional, lateral, structural and dynamic response-analyses of multiple design configurations all within a very strict space envelope. SwRI then created a complete detailed drawing package (mechanical, electrical, instrumentation, control) used for fabrication of the stand which included:

20'L x 13'W x 23'H Footprint
13,500 ft-lb Torque Rated
2,000 rpm
13,000 lb of I-Beam Structures
32,000 lb of Steel Plate and Tubing
33,600 lb Electrical Motor
2 Electrical Motors and Gearboxes: 4,350 hp and 250 hp

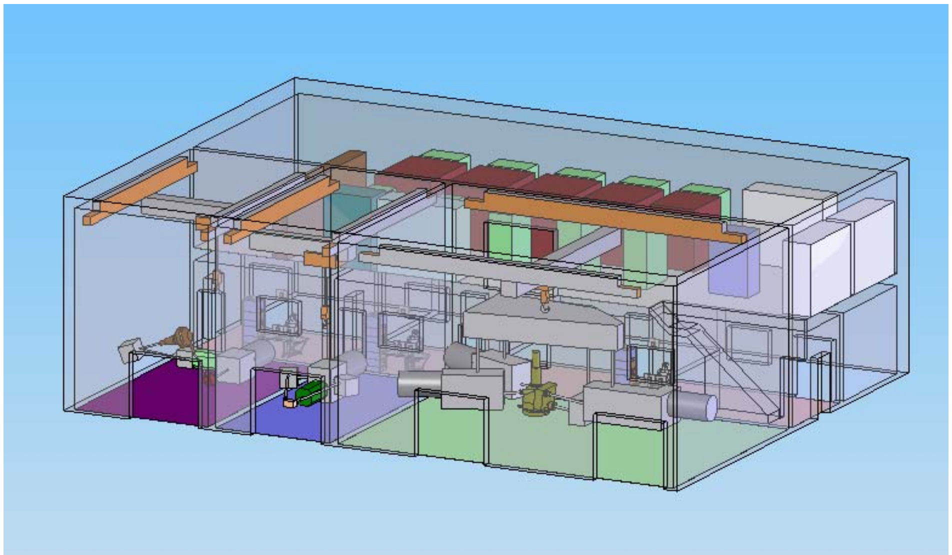
Other functional areas that were defined included hydraulic systems, pressurized bearing lubrication across three multiple rotating surfaces, oil temperature conditioning circuits, data acquisition, and facility electrical power. Some representative models of the test stand are shown below.

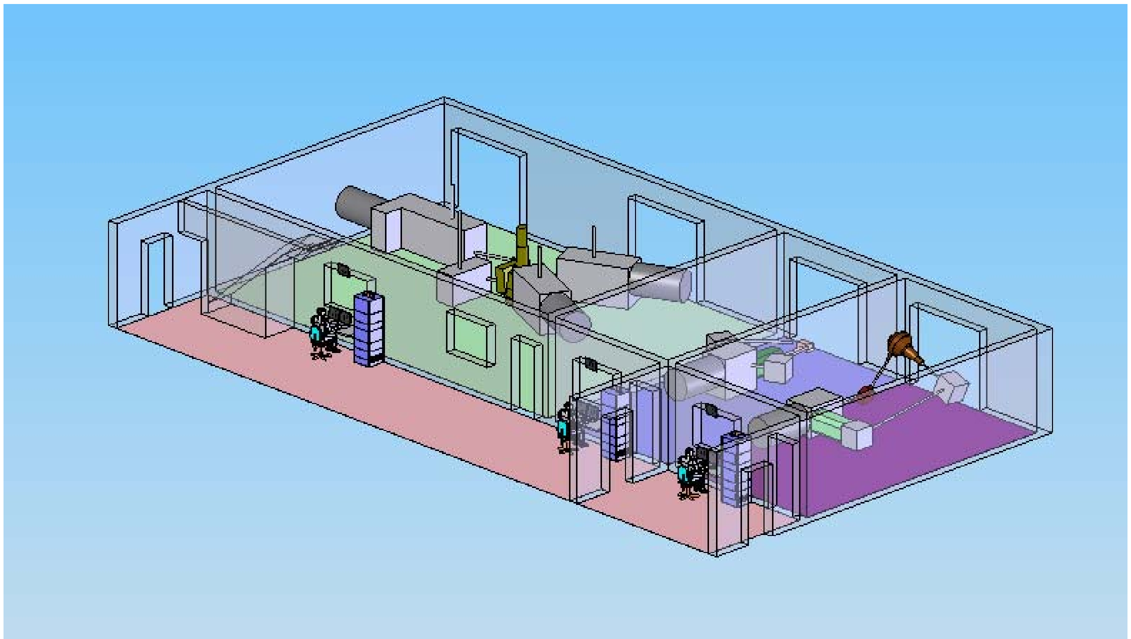


TEST FACILITIES

SwRI has been involved in a number of helicopter test facility designs for both the United States Army and for helicopter manufacturers. One such project was for the next generation, heavy lift helicopter. This helicopter is configured with three 10,000 hp gas turbine engines, which drive through two nose gearboxes into a 30,000 hp main transmission. Output from the transmission sends 25,000 hp to the blade and 5,000 hp to the intermediate/tail gearboxes. The torque transmitted to the blade is 750,000 ft-lb. The test facility consists of the following:

98,000 lb of steel structure
90,000 hp of facility gearboxes
7000 hp of electric motors/drives
155 instrumentation sensors
15 PID controllers
3 computer systems

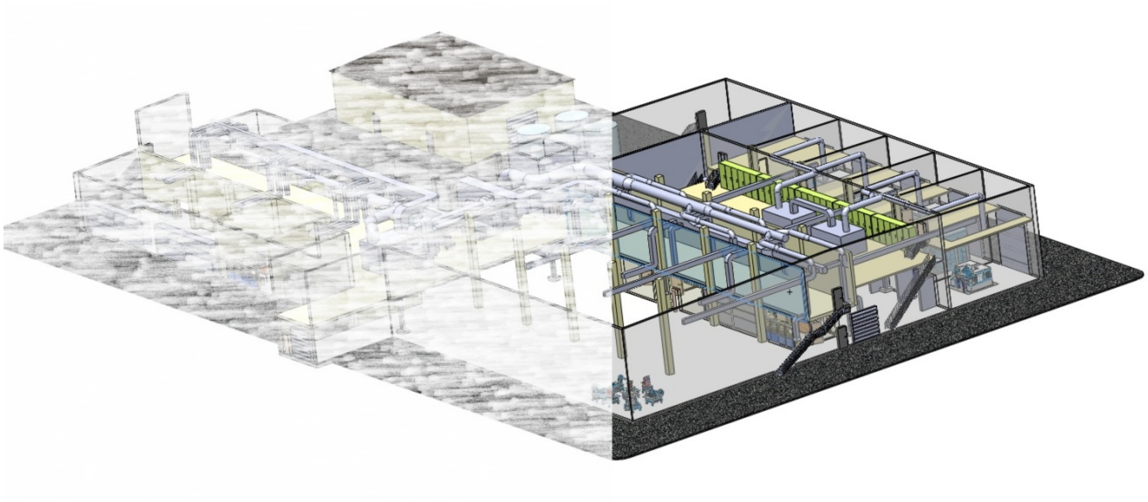




A second was a clean sheet design for a US Army Depot helicopter engine and transmission facility with the most challenging being the emphasis on the nine transmission test cells. For various reasons this included a mix of different types of test stands including mechanically regenerative and electrically regenerative types. One area of emphasis for these test stands was the electric motors and generators, of which air and water cooling was used.

A major challenge for the Army at this depot was to provide the type of flexibility needed to adapt to a mix of different helicopter models transmissions. This was further compounded by the requirements to test quantities of the various different models for which advanced planning simply was not possible, as it was a function of helicopter usage in multiple battlefield locations around the world.

A model of this facility is shown in the figure below which highlights the transmission test cell portion of the test facility.



For additional information, please contact Mike Kluger at 210 522 3095 or mkluger@swri.org