Electronics, string, and glue
The electronics which Bell president "Jack"
Horner lists as one of three elements which
dominate Bell business these days are
increasingly evident on the production line.
Many millions of dollars have been invested
in computer-linked manufacturing equipment which has been introduced to keep track of composite structures throughout the whole design-to-finish-product process.

Bell's responsibility for the V-22 full-scale development phase is to fabricate the wing, nacelles, and rotor system. With V-22 partner Boeing Vertol, the company says that the project "represents a significant step forward in technology". The airframe, being developed by Boeing, is about 60 per cent carbon/epoxy (the string and glue elements), with the usual attributes claimed for such construction: higher stiffness, lower weight, and improved productivity.

The Texas manufacturer emphasises the "leading-edge technologies" which it has developed in preparing for Osprey production, listing the wing, pylon-support, and rotor assemblies as particularly important. Wing torque-box components (spars, ribs, stif-fened, and shims) present no significant manufacturing problems by themselves. Apart from the large one-piece wing skin, Bell acknowledges that similar parts have been produced in the past.

It was the fabrication and management of thousands of individual composite plies that gave Bell most concern. A solution has been found in Bell's Integrated Composite Ply Cutting Centre (CCC), which is managed by a Composite Process System (CPS).
In the CPS, the engineering ply table (which serves as the data master) is transferred from the computer-aided design and manufacturing (Cadam) database to the computer-aided planning (CAP) system. Here the ply table is used to develop the sequence for laying-up parts and to establish requirements for the loft, which in turn develops flat patterns and generates ply area and length and minimum-rectangle statistics.

The minimum rectangle area is used to determine the amount of composite materials required and the CPS reviews material on hand. Work is divided into 8hr blocks, which

are tied to factory manpower. The CPS also divides the work into groups that can be nested and cut from the same blanket.

Bar-code technology is being used to keep track of composite plies, which are critical for three reasons, according to Bell: uncured materials have a limited shelf life, the huge numbers would swamp a conventional system, and layup of individual plies must be performed in an exact order and location. Bar-code readers log each roll of material out of the freezer, starting the shelf-life clock. Individual labels are attached to plies after cutting, and this record locates each ply for the computer. Wand readers are used by fabri-cators to ensure that layup is done corrrectly. The system enables Bell to maintain complete records of all composite parts while reducing scrap and labour costs.

The CCC uses commercially available hardware and software, in preference to technology developed within the company, because Bell does not find such in-house activities economically viable. It will have the capability to process up to 10,0001b of material a week over the next three years. Having organised, simplified, and maxi-mised material cutting and collating, the system will produce complete kits in layup sequence, with each ply bar-coded and having sufficient shelf life for layup, staging, and cure in Bell's autoclaves. The CCC will use three Gerber cutters (two of which will have semi-automatic material dispensers), a flat-panel tape layer, semi-automated kit packager and slitting machines, label printers, and an improved nesting system. Uncured composite "blankets" will be dispensed automatically on to the cutting surface. The computer-driven high-speed chisel will cut out shapes at up to 500in/min at a tolerance of 0 • 003in.

Bell designers have integrated the com-puterised systems to facilitate manufacture and fabrication. Accordingly, the wing torque-box design has plies grouped into modules to eliminate ply-by-ply layup. Tooling holes and tabs indentify any misplaced stacking.
To automate wing-skin fabrication, Bell has introduced an Ingersoll ten-axis auto-mated tape layer which is said to improve productivity threefold. The machine can lay

tape on a severe compound curvature surface. A natural-path program may be generated to allow the tape to be placed over contour changes without distortion.
Bell claims that manufacturing the V-22 pylon support and spindle was a challenge to existing technology. The two components are described as complex carbon-epoxy struc-tures. Initially, Bell used filament winding on a male mandrel for the spindle, which required five cure cycles. This has been reduced to two stages by switching to a female tool and using bladder expansion. The next step is to machine from solid graphite, which is 40 per cent cheaper than a carbon-epoxy tool, will eliminate a further cure cycle, and will require only end-trim machining.

The pylon support comprises more than 400 carbon-epoxy plies and unidirectional tape. To control the spindle/pylon interface, male tooling must be used. Indexing tabs, rather then tooling holes, are used to locate plies and to reduce fabrication time.
The manufacturer says that making the V-22 rotor blades present a unique challenge because the 45° twist requires a complex spar structure whose filament-wound glassfibre-epoxy straps are also twisted. To overcome problems arising with the uncured strap—wrinkles could reduce strength—Bell developed a process to wind the straps flat, with blade twist being added at the compaction stage.

Bell had to enroll the joint efforts of its engineering and manufacturing departments to finalise the configuration of the grip, which it describes as "by far the most complex composite structure designed to date". The grip is the portion of the hub assembly which retains each blade and houses the pitch-change bearing. It is a carbon-epoxy filament-wound structure requiring precisely placed fabric reinforcement plies and racetrack layers of filaments.

The V-22 swashplate is a flat triangular toroid which would normally require a salt or wax mandrel as a tool. Since the outer surface has to be machined, Bell has gone for a nylon blow-moulded mandrel which is sufficiently rigid to support material layup but soft enough to be used as a pressure bag during
curing. Bonded to the epoxy, the mandrel
forms a non-removable flyaway bag. Bell says
that the V-22 grip, pylon-support assembly,
and swashplate demonstrate the company's
leadership in composite manufacturing.

This 39-seat aircraft is one of several civil tilt-rotor developments being studied with Boeing Coutoumanous emphasises tha t the LH X contest has several major elements
and tha t prowess in one will not guarantee
victory. "A Mach 1 • 25 helicopter flying at
65,000ft unrefuelled to Cairo and back
wouldn't be good enough to win, because
performance is only 20 per cent."

For the next few years, military work will dominate Bell business. Currently 52 per cent is for the U S Government, with 37 per cent being civil and military work outside the USA. Th e remaining 11 per cent of business is for U S commercial

customers. Th e cyclic nature of the busi-ness is illustrated by the fact tha t in 1981-82 just 20 per cent was for the U S Government

With the V-22 and LH X programme,
the prospective 400 civil series, and a new
plant coming on line in Canada, Jack
Horner has his thum b in several pies. He
will be hoping to emulate his namesake in
most of them. D

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