, investigated without affecting safety. The RAE is also working, with some success, on direct voice control of navigation and communication. Voice command of the flight control system is unlikely in the near term, however, foT consistency and accuracy problems remain to be satisfactorily resolved.

Basing its work on the RAE's results, British Aerospace continued its own research, the first phase of which ends next month. BAe has flown its One-Eleven with a very small degree of instability, using water ballast to shift the e.g. rearwards. The programme has been extremely successful, says BAe technical research chief Harry Hitch. One of the conclusions is that there is little advan-tage in exceeding the neutral stability margin in civil aircraft. Negative stability calls for a fully active control system, with its attendant redundancy problems, but more interestingly it means that questions arise over the positioning of the main undercarriage, since the aircraft's e.g. is moved aft. An alternative is to move the e.g. after take-off by shifting fuel, a system already used on Concorde.
Most advanced flight controls research in the USA has been applied to fighters such as the F-16 and F-18, to improve handling and reduce drag. However, under a Nasa contract Lockheed has devoted considerable effort to reducing the trim drag of a TriStar fitted with active pitch control and a water ballast system to move the e.g. aft. Trim drag reductions of two per cent were achieved which would, in service, yield fuel-burn savings of the same amount. The company has also carried out theoretical and simulator studies, based on a TriStar, of the effect of operating the aircraft with 10 per cent static instability, using a more sophis-ticated pitch control system.
Lockheed was the world's first manu-facturer to introduce active aileron control to passenger aircraft, reducing fuel burn of TriStar 500s by around three per cent. The ailerons are driven by a Collins digital flight control system—the first such equipment to receive FAA certification for category IIIA conditions.
Despite Lockheed's work the USA appears to be lagging behind Europe in the introduction of fly-by-wire control to passenger aircraft. This is partly due to market circumstances, Boeing having opted to derive or improve existing aircraft rather than introduce a new type to compete with the A320. Boeing's most interesting work to date on advanced flight controls was seen in the YC-14 Stol transport aircraft, which needed a full-authority fly-by-wire system to reduce pilot workload under difficult asymmetric and low-speed conditions. A radical, but very effective triplex redundant digitally controlled system was designed by GEC Avionics (then Marconi-Elliot), which won the flight controls contract. Elec-trical isolation of the three channels was achieved using time multiplexed fibreoptic links, an idea which has found favour in subsequent military fly-by-wire aircraft.
The Boeing 757 and 767 incorporated full authority digital fly-by-wire control

msmm HI W@mm* lt§ ^ESeSg
ifdbipi mM mi

IIP
"' -? '?

•^fe
y£' "iVvvsV $'•"•'

ijg$jj£vr

iii^iiilillWPPIK
.- v ^'' v ^ •''' \-*s£M&t>&

S^'ife^^'S H
s.*;'j

v v;. " tf-r-jO \ vf,-/; '-'••"•''

g^fert^g^

'Ifi

W^^W^^^MWiM^^M^^^S^IMW^W^^W^^^^ ^&BSBB!SK§$,

-'m~^'':''y

'' iv^?.'S^Kv™
^^^S^^3^*^ffi^«B> %

?-*';V

''

,

- ^*i',,:,v

'* '',' ' ! ^ Vx:,

'**VvN!v*;' ' '•.•-' '.".

' '.'. '••'• <**.".!. ^-•-•..'V'-"- ' ' ' • •:•':

•'•' '•''*• • *'"••• ' • " ' • •

,>C"'V."-i«'; .'.• .•\s?'\\i<

i?-y:'••%•'..''''• • *:••'• ' '''•'•$$^'$£*'

f§fii*|lB*

!B
-

:'*L
'"'' * n? *^!l,i*^^^^^^^^S

^K.,:.Sfc^S^^S ft^ '^^t

7: .^^^Wl^;

-1^^to

^^^^^^^^^^:
^-lllipp

:'.^ C ' '• '• '•.":- ':

* <; ^S^^^^^^^^^^ ^

^ ^ ™

The first Skyship 600 equipped with fibreoptic control signalling will fly later this year

only in their spoilers, whereas the A310
(and subsequently the A300-600) has
digitally controlled slats and flaps as well.
The apparent conservatism in reliance on
digital computers will end with Boeing's
1992 aircraft now under development. Boeing passenger aircraft, traditionally built with a 12 per cent stability margin (at the aft e.g. limit), will become neutrally stable and totally reliant on fly-by-wire control, with no mechanical backup. Boeing's vice-president in charge of prod-uct development, Jim Johnson (who was the chief 757 development engineer), is clear about the need to switch over to full electronic control of the aircraft from the start. Retention of mechanical backup, he says, is unsatisfactory, since it means having two completely different types of control system. "It's a difficult interface," he says.

With neutral stability, the 1992 Boeing will benefit from a two per cent trim drag reduction, says Johnson. Tail surface area will be reduced slightly as a result, "but not to the untrained eye". Unlike Airbus, Boeing has opted not to have gust/load alleviation, which, in the A320, reduces wing bending moments and allows a lighter structure. This may be because the benefits are minimised with underwing engines (rear-mounted ultra bypass engines are being considered, however.) Boeing also says that its wing design, while fundamentally similar to that of the competition, is such that load alleviation is unnecessary. Johnson does not rule out such a system in later aircraft.

The principal benefits of a fully fly-by-wire flight control system will, says John-son, be in a weight saving of "several hundred pounds" through the elimination of cables and pulleys, and in the ability to give every aircraft in Boeing's range identical handling characteristics through

24

software programming (rather than aerodynamic and mechanical control tail-oring, as in the 757 and 767). Handling commonality cuts training costs and greatly increases operational flexibility, because any pilot can fly any aircraft in the fleet.

Another important fly-by-wire spin-off
is in the reduction in maintenance costs through having a single part number computer to perform control functions in all three axes. Hardware will be identical throughout—the computer being given its identity by programming.
In some military aircraft electronic con-trol is being used to improve performance throughout the flight envelope by com-manding changes in wing configuration. Swing-wing aircraft have been flying for some time (F-lll, B-l, Tornado, F-14), and variable camber is due to be tested this year by Nasa on an F-lll. Such "intelligent" variable camber wings are being studied for civil aircraft, and pro-mise useful weight and drag reductions, with consequent savings in fuel.

Together with Lockheed, Boeing is carrying out extensive studies into an "all-electric" aircraft under contract to Nasa. In its ultimate form, all flight controls, landing gear, air conditioning, and other non-propulsion services are electrically powered, eliminating the need for complex, high-pressure hydraulic systems and the constant fuel-thirsty drain on engine-supplied bleed air. The key is the introduction of extremely powerful electric motors and generators using samarium cobalt magnets. Used for flight-surface movement, such motors would either be located next to the actuator, spinning up very quickly on command to drive a small local pump to power the hydraulic jack, or would become an integral part of the control surface

FLIGHT International, 6 July 1985