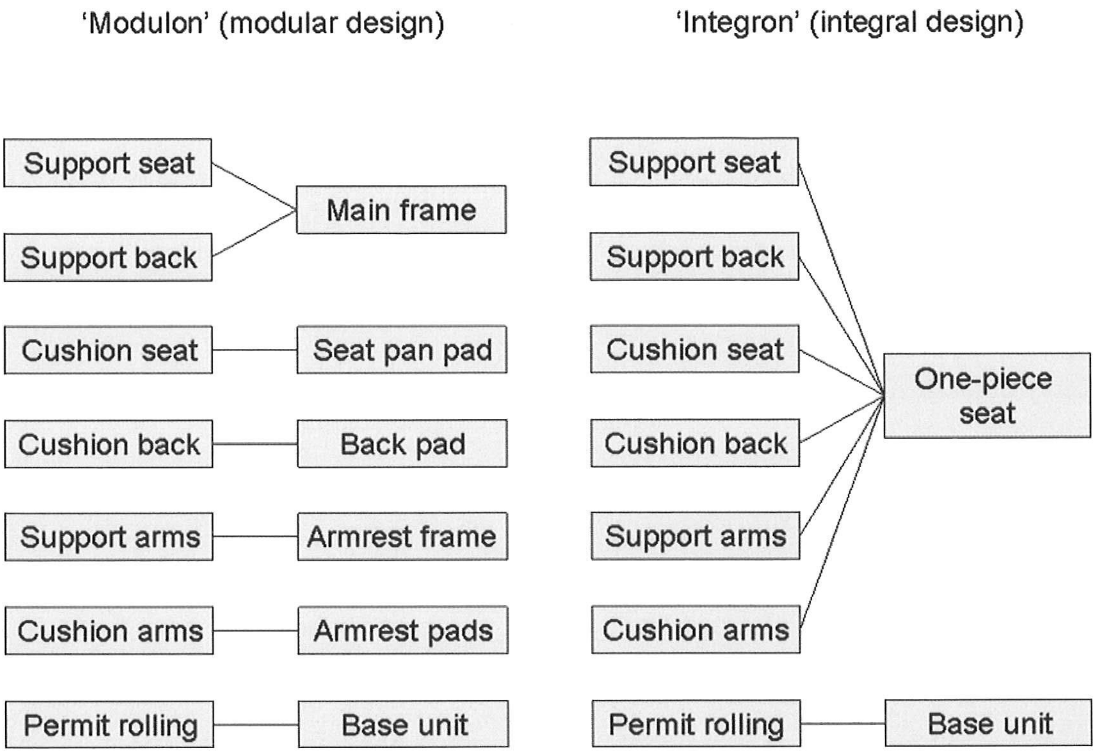
1 (a)



(b) (i) As compared to the integrated architecture, the modular architecture has the following benefits for the design process:

> The design of each module can be assigned to a different team member in the knowledge that that team member is entirely responsible for a particular function. (For the integrated architecture, assigning modules to team members will be difficult because a close coordination between different teams will be required.)

> Modifications made to any particular module need not influence the design of the other modules. (For the integrated architecture, changing the design of any one module/feature may necessitate the redesign (or at least the review) of other modules/features.)

> If the chair is failing to perform a particular function adequately it will be clear which module requires replacement or redesign. (For the integrated architecture, if the chair fails to perform a particular

function adequately it may be necessary to redesign many different modules/features.)

> Existing design knowledge from previous projects can be reused for this project, and designs from this project can be reused in future projects. (For the integrated architecture, reuse of design knowledge will be more limited.)

(b) (ii) As compared to the integrated architecture, the modular architecture has the benefit that existing components from previous projects can be reused. This reduces inventory and logistics problems. (For the integrated architecture, reuse of existing components will be more limited because many of those components will be unique.) Any later product ranges will also cost less to manufacture for the modular architecture because of commonality between components and interfaces across the range.

With the modular architecture, the ability to make the chair suitable for different floor surfaces by only changing the casters (rather than the entire base unit) permits the firm to employ a strategy of "deferred differentiation". Chair assemblies could be shipped to different territories, and distribution centres, with caster choice being made shortly before, or at, the time the customers place their orders. If there are unanticipated changes in the proportion of caster types that any given territory expresses a preference for, it is only the relatively small and light casters that need to be redistributed. It is also likely that the modular design can be collapsed in some way for distribution, with the final assembly taking place close to, or at, the customer's location. This would reduce the size of each unit during distribution, and therefore reduce costs.

Note, however, that because the integrated architecture permits function sharing, there is increased opportunity for optimising the performance of the overall product according to a number of different variables, including mass. Consequently, the integrated architecture may result in a lighter product which would reduce distribution costs.

(b) (iii) Product variety.

The architectural decision will influence the firm's ability to offer variety along the following dimensions:

- *Performance* – The modular design makes it easier for the firm to vary the performance of individual components (e.g. the padding softness, suspension compliance, material quality, etc.). However, overall performance (e.g. total mass, price, aesthetics) can be optimised for the integrated design and therefore the individual chairs can perform at a higher level.

- *Features* – The modular design makes it easier for the firm to offer different chairs with different features (e.g. armrests, headrest, adjustments).

- *Size* – The modular design permits the firm to later offer a range of size offerings (e.g. shorter seat pan, higher back, thicker padding) without changing large assemblies or the entire product.

- *Localisation* – The modular design permits the firm to offer specific solutions for different territories (e.g. seat padding suited to local temperature, humidity, aesthetic preferences).

(b) (iv) Product change.

The architectural decision will influence the firm's ability to offer product change along the following dimensions:

- *Upgrades* – The modular design permits the firm to offer customers future upgrades (e.g. leather covers, 'floating' mechanisms, chrome base units).

- *Add-ons* – The modular design permits the firm to offer customers future add-ons (e.g. arm rests, head rests, keyboard rests and mouse mats).

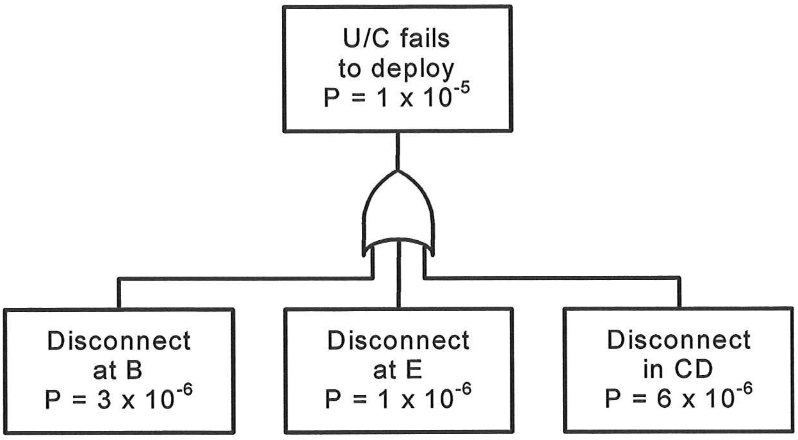
- *Adaptation* – The chairs may be expected to have a long life in the market and perform in different environments over that life. The modular design permits the firm to offer customers future adaptations (e.g. covering materials suited to different environments such as chemical resistant or wipe-clean, higher base units for elevated position such as assembly line or drafting)

- *Wear/maintenance* – The modular design permits the firm to offer customers future replacement of worn out components (e.g. fabric, compliant mountings, casters).

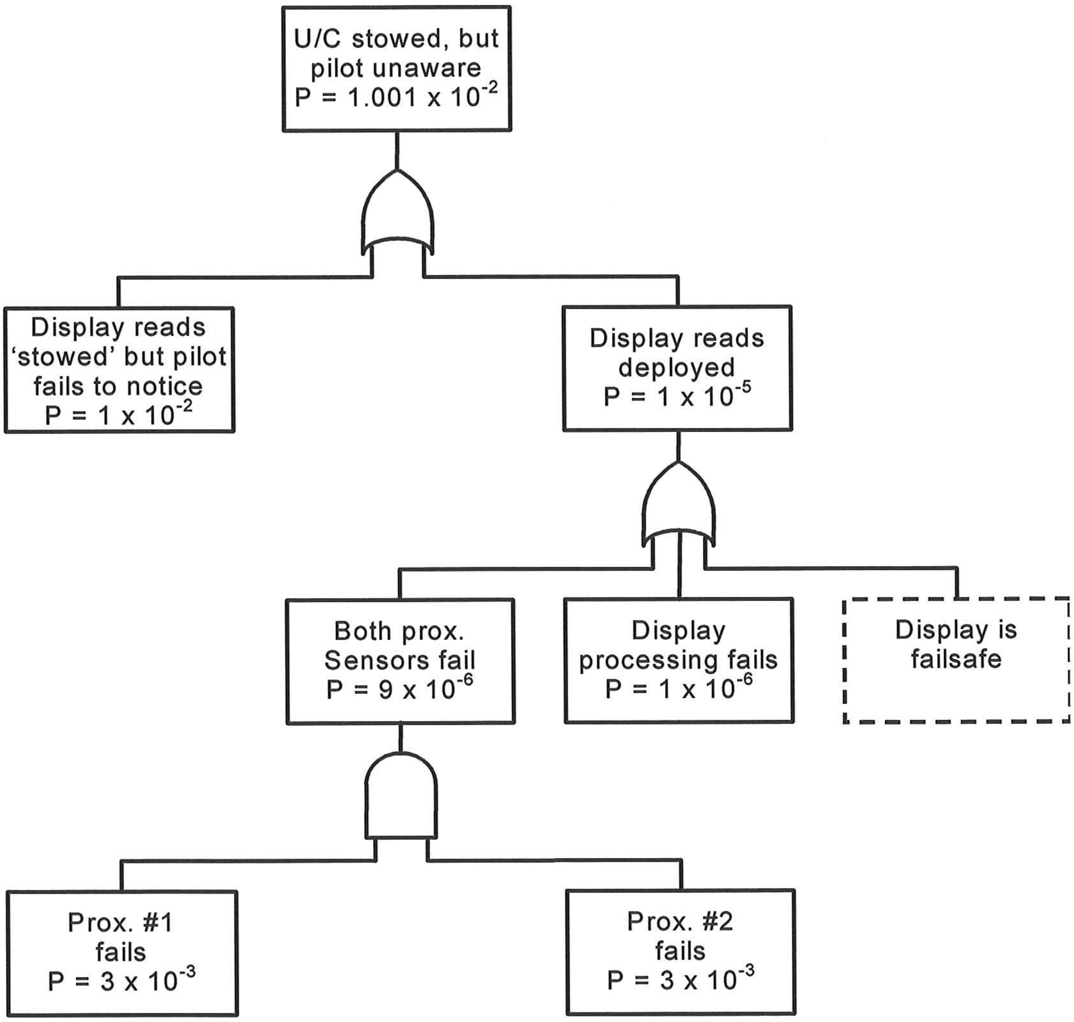
Assessor's comment:

This question was very popular. The mapping between components and functions was generally done correctly. Very occasionally, candidates tried to map component to components (instead to functions). Most candidates correctly accounted for the influence of the architecture on the processes of design, manufacturing and distribution, but the reuse of parts and the reuse use of knowledge were seldom mentioned. The influence of architecture on potential product variety and product change was generally well understood.

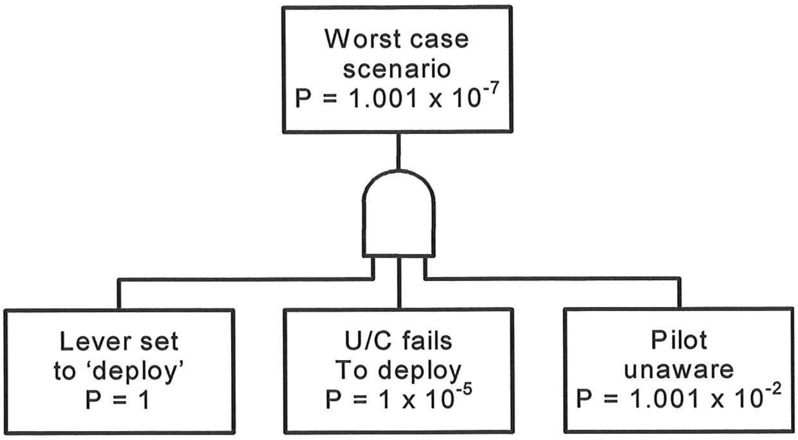
2 (a)


U/C fails
to deploy
P = 1 x 10-5
Disconnect
at B
P = 3 x 10-6
Disconnect
at E
P = 1 x 10-6
Disconnect
in CD
P = 6 x 10-6

(b)


U/C stowed, but
pilot unaware
P = 1.001 x 10-2
Display reads
'stowed' but pilot
fails to notice
P = 1 x 10-2
Display reads
deployed
P = 1 x 10-5
Both prox.
Sensors fail
P = 9 x 10-6
Display
processing fails
P = 1 x 10-6
Display is
failsafe
Prox. #1
fails
P = 3 x 10-3
Prox. #2
fails
P = 3 x 10-3

(c)



(d) (i) Pilot error: Pilot awareness dominates due to pilot error. Add audio warning or other 'unavoidable'/'unignorable' signal should be used. IF pilot error approximates to zero, then likelihood that pilot is unaware that the u/c is stowed becomes $p = 10^{-5}$ (1000 times safer), likelihood of worst case scenario becomes $p = 10^{-10}$ (also 1000 times safer). This is the biggest possible gain in safety for the system (short of having a fixed undercarriage, etc.)

Likelihood that pilot is unaware then becomes equal to likelihood that u/c fails to deploy.

(d) (ii) Break in wire: Reverse the default behaviour of actuator D so that it retracts in the absence of a signal (failsafe). This would reduce the likelihood that the u/c fails to deploy to from $p = 10^{-5}$ to $p = 4\times10^{-6}$ (40% reduction).

(d) (iii) Prox sensors: adding a third prox sensor (triplex parallel redundancy) would change the likelihood of combined sensor failure from $p = 9\times10^{-6}$ to $p = 2.7\times10^{-8}$.

(d) (iv) Disconnect at B: reverse spring direction so that default condition is encoder extended (failsafe). Decreases likelihood that undercarriage fails to deploy by 3×10^{-6}.

(d) (v) Disconnect at E: reverse spring direction so that default condition is undercarriage deployed (failsafe). Decreases likelihood that undercarriage fails to deploy by 1×10^{-6}.

Assessor's comment:

This question was popular. Many candidates drew the fault tree diagrams and did the associated probability calculations completely correctly. However, some candidates failed to interpret the provided data appropriately and thus constructed incorrect fault trees. The most common errors here were overlooking the redundant components and considering the failsafe components. Most candidates suggested five possible design improvements. Only some candidates explicitly prioritise their suggestions, and only a very few make reasonable efforts to quantify the improvements made.

3 (a) As per example in notes for H7 – k6 fit.

	min	max	mean	sd
hole H7	50.000	50.030	50.015	0.005
shaft k6	50.002	50.021	50.012	0.003
c			0.0035	0.0059
z			-0.591	
p			0.723	

Probability of an interference fit = 27.7%.

As per example in notes for H7 – n6 fit.

	min	max	mean	sd
hole H7	50.000	50.030	50.015	0.005
shaft n6	50.020	50.039	50.030	0.003
c			-0.0145	0.0059
z			2.450	
p			0.007	

Probability of an interference fit = 99.3%.

(b) Reversing the calculation for H7 – p6 fit.

	min	max	mean	sd
hole H7	50.039	50.069	50.054	0.005
shaft p6	50.032	50.051	50.042	0.003
c			0.01217	0.0059
z			-2.0537	
p			0.98	

Original H7 fit

hole H7	50.000	50.030	50.015	0.005

Minimum heating time = 3.1 minutes.

Reversing the calculation for H7 – s6 fit.

	min	max	mean	sd
hole H7	50.060	50.090	50.075	0.005
shaft s6	50.053	50.072	50.063	0.003
c			0.01217	0.0059
z			-2.0537	
p			0.98	

Original H7 fit

hole H7	50.000	50.030	50.015	0.005

Minimum heating time = 4.8 minutes.

(c) Heat the bearing to insert the shaft, then heat the housing to insert the bearing/shaft assembly OR heat the housing the insert the bearing, then heat the housing/bearing assembly to insert the shaft.

(d) A more pragmatic 'fit' would allow for some clearance to allow assembly. This would increase the probabilities for a 'pragmatic' interference fit and increase the times required to enable a clearance fit prior to assembly.

Assessor's comment:

The least popular question on the paper, despite being based on the same example as in the lecture notes. This question required candidates to analyse a range of hole/shaft 'fit' problems using a probabilistic approach. Part (a), most candidates had a good sense of direction, but also ended up with the wrong answer. (b) The reverse problem to (a) was generally done less well. (c) Generally answered well. (d) Generally answered well.

4 Many possibilities here. Ideas ranging from scraping to heating/drying to gritting. Best solutions will look at the practicalities of the solution proposed. Can heating be achieved? Will scrapping work? Can enough grit be carried? etc.

Assessor's comment:

A popular question requiring the conceptual design of a snow clearing machine. Part (a), generally answered well. (b) Generally answered well, but often lacking in measurable performance targets. (c) A variety of diagrams, often too simplistic, but a number of excellent answers. (d) Generally done rather poorly with most solutions based on existing lawnmowers, but with insufficient detail to describe how the product would work. (e) Bookwork generally done poorly.