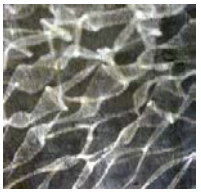

# Heterogeneities$_{DOT}$net

# ON HIDDEN HETEROGENEITIES: COMPLEXITY, FORMALISM AND AIRCRAFT DESIGN *

**John Law**

> 'You don't have a map in your head, as a child. Later, you have the globe – the seas and the shapes – and you can't ever get back to that emptiness, that mystery. Knowing that there are other places, but not knowing where they are, or how to get there.'
> (Penelope Lively, City of the Mind, Harmondsworth, Middlesex: Penguin, 1992, pages 121-122)
> '... mimesis fuses brilliantly with alterity to achieve the connection necessary for magical effect, the connection I have earlier alluded to as a kind of electricity, an ac/dc pattern of rapid oscillations of difference. It is the artful combination, the playing with the combinatorial perplexity, that is necessary; a magnificent excessiveness over and beyond the fact that mimesis implies alterity as its flip-side. The full effect occurs when the necessary impossibility is attained, when mimesis becomes alterity. Then, and only then can spirit and matter, history and nature, flow into each others' otherness.'
> (Michael Taussig, Mimesis and Alterity: a Particular History of the Senses, New York, Routledge, 1993, pages 191-192)

## First Story

It was to be 84 feet long, 23 feet high, and 35 feet from wing tip to wing tip. It was called the P17A. And it was – it is – the design for an aircraft, a military aircraft, submitted by the aircraft manufacturer, English Electric Company, to the British government in 1958.

I will talk about its wings, about the design of its wings.

Like a paper dart, these were to be delta-shaped, their leading edge swept back at $50^{o}$. They were to be thin – their thickness only 2.5% of their breadth at the tip. They were to be short and broad – their aspect

ratio (the span from wing tip to wing tip divided by gross surface area) was to be 2.77. And their gross surface area was to be 597.3 square feet.[1]

So why were they to have this shape? What was the reasoning that lay behind them? This is the topic of this chapter: it is a study in design, in complexity as heterogeneity, and in particular, in the multiplicity of heterogeneity.

The story starts with a formalism which helps to express or explain, or to impose exigencies on the shape of the wings. However, this formalism also does a lot more. Look at the following which comes from the English Electric brochure on the P17A:

$$G = \frac{(\text{velocity} \times \text{lift slope})}{\text{wing loading}} = \frac{M.a_t}{W/S} \qquad (1)^2$$

Let me define the terms, for these are terms that can be linked to the words that appear in the less formal part of the expression.

- M is Mach number, the speed of sound, so M=2 would be twice the speed of sound, and so on
- $a_t$ is transonic lift slope, of which more in a moment.
- W is the weight of the aircraft.
- S is the wing area.
- And G is a measure of the response of the aircraft as it flies through vertical gusts of wind.

The expression is a way of expressing what aerodynamicists call ‘gust response’. It is a quantification of the susceptibility of an aircraft to vertical buffeting. The aircraft, or so the expression tells us, will be buffeted less if it weighs more, and it will be buffeted more if it flies faster, if it has a larger wing, and if its lift slope is higher.

## Difference

This wing, and the formalism from the English Electric Brochure, have much to tell us about complexities, and in particular with the complexities that come with absences that are also presences, those complexities that come with Othernesses that are both expelled and drawn in. It has much

to say about the complexities of that which is not pure or clean or homogeneous, but rather carry what is different within. I will think of these as the complexities of heterogeneity.

The tools that I'll use to think about this derive from semiotics. A reminder: semiotics is the study of relations. More specifically, it is the argument that terms, objects, entities, are formed in difference between one another. The argument is that they don't have essential attributes but instead achieve their significance in terms of their relations, relations of difference.

It is easy to apply semiotics to a formalism such as the one above, for this is the distribution of a visible set of relations, a set of differences which helps to determine the significance or role of the terms that are linked together. For instance, it establishes the difference between gust response and velocity. There are, as they say, 'variables' which intervene between these, such as lift slope and wing loading. If everything else were equal, if these variables were not to intervene, then gust response and velocity would vary together – which they don't, because it is rare for everything to be equal.

But is everything there? To pose the question is to suggest the answer. Something, indeed much, is missing. In one way this is blindingly obvious, for the distributions made by formalisms don't stand alone. But what is missing? This is my concern, the point of an inquiry into complexity as heterogeneity. It is an inquiry that requires that we turn up the magnification of the stories and look in more detail at their terms with the hope of exposing and investigating a list of heterogeneities.

## Second Story

If we magnify the formalism when what we see depends on what we choose to magnify and where we look. I'll magnify it in various ways in the course of this chapter, but I'll start first with the term that I left hanging in the air, that of lift slope. We already know something about lift slope. We know that it is related to, but different from, gust response and the other terms in the formalism. But outside the formalism the term is idle, a short cut. It doesn't tell us anything. So what happens if we magnify it? What do we discover?

The answer is that it decomposes turning from single term into a relation between two further terms. So this is another difference, another specified difference. And the new terms are 'lift' and 'angle of attack'.

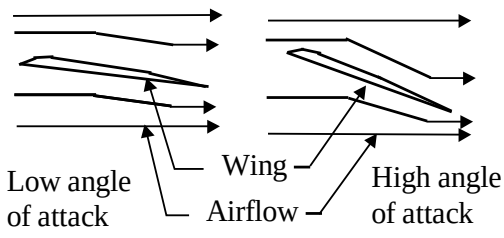


Figure 1: Relationship between angle of attack and lift. If the increase in lift with increase in angle of attack is small then lift curve slope is low.

Some definitions.

- Lift is the lifting force of a wing as it moves through the air. In engineering this is usually written $C_L$.
- Angle of attack, written $\alpha$, is (roughly) the angle between the wing and the air through which it is travelling.
- And lift slope is the slope of the curve that links the two for a given wing if they are laid out as the two coordinates of a graph (see Figure 2).

All of this means that if lift slope is low, then lift doesn't change much as the angle of attack alters and the curve is flattish – and if it is high then it does.

**Heterogeneity/simplicity**

If we magnify the term 'lift slope' in this way then we introduce a further set of differences. If we wished might write them into expression (1) to produce something like this:

$$G = \frac{\text{velocity} \times (\text{change in lift coefficient/ change in angle of attack})}{\text{aircraft weight} / \text{wing area}} = \frac{M.(dC_L / d\alpha)}{W / S} \quad (2)$$

We might work at this formalism to rearrange its terms and simplify it a little. But let's make another point. This new formalism is more complicated than the old though it's not unmanageable, at least not yet. But if we were to expand the other terms – for instance unpacking the calcula-

tions that lead to Mach number, M, it would grow still further. And, no doubt, it could be expanded in other directions too.

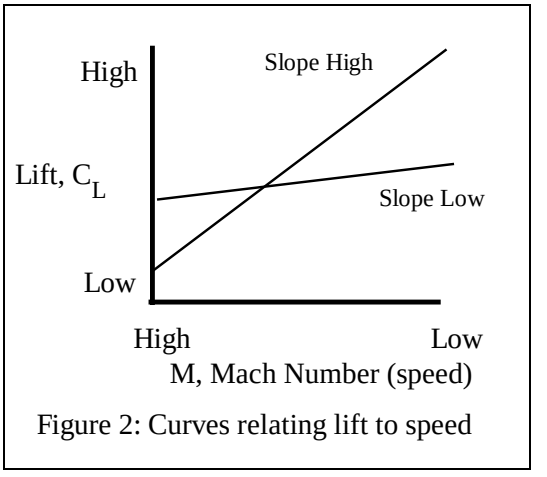

Figure 2: Curves relating lift to speed

What might we make of this? One answer is that design is all about distributing relations of difference, but that only some of these are relations of presence. Only some of them crop up together on the page. The corollary is that the making of this centre, this formalism, performs many other relations including links that are relations of absence. In one way or another, and for one reason or another, there are limits to the relations made present.

I want to suggest that there are several logics of absence or alterity and I will point to some of these shortly. But, looking at the formalism above, there is a straightforward and immediate version of the logic of absence. This is the fact that it is easier to handle formalisms with fewer terms than those with more (though the same logic applies just as much to non-formalisms). So this, perhaps, is a basic design principle, a basic feature of the character of making centres, of making designs – that present complexity is self-limiting.[3]

I'm going to call this heterogeneity/simplicity. If we put the 'heterogeneity' on one side for the moment then by simplicity I mean, straightforwardly, that there is not enough room for everything. Not everything can crowd into a single place, and implosion, or perhaps better condensation, is impracticable. Perhaps this is a general principle, but linked to concern with design and control it's what the actor-network theorists point to when they tell of 'punctualisation'[4]. That which is complicated comes in simple packages – like lift slope – which can be used to make sense.

**Third Story**

In the paragraph immediately after the formalism in the Brochure we read the following: 'By comparing several aircraft, of known characteristics, which have been flown in low altitude turbulence, it is possible to decide a maximum value for this parameter which will ensure a comfortable flight.'[5] 'This parameter' is G, gust response again.

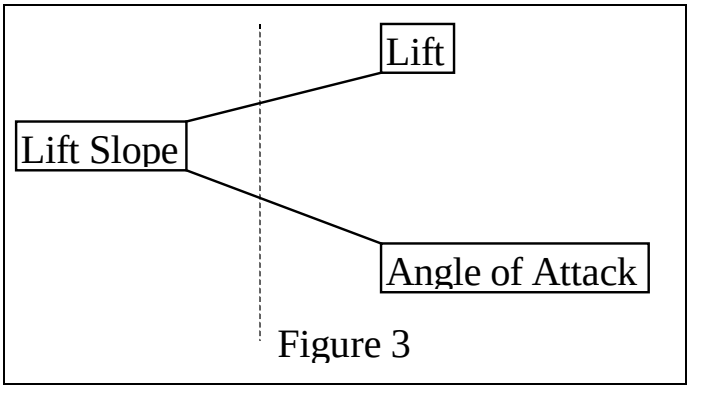

Figure 3

**Heterogeneity and absence/presence**

On the one hand the two paragraphs are contiguous. It is reasonable to imagine continuity, co-presence, and more relations of difference. But as we read on and a moment passes, so the field of presence starts to shift. Before, it was a matter of formalisms, terms that stood in quantifiable relations with one another. Now it is something different.

When we looked at that formalism we already knew that something was absent. We knew that there was one kind of logic at work, a logic of absence. We also knew that this absence was an engineering/algebraic logic, one of pragmatic simplicity, the business of limiting complication in order to secure ease of manipulation. But there were other kinds of absence too. Indeed in order to make the narrative work I let slip a clue, for by referring to 'lift slope' as 'idle' I traded on another absence: the suspicion that the reader would 'know' what was meant by such terms as 'weight' or 'surface area' – which, by implication, were not idle. This, then, was another logic of absence.

The second paragraph, the one that makes my 'third story', takes us in another direction. It tells us new kinds of relations are being performed,

relations that no longer have to do with formalisms but, rather with the flying of aircraft. I will delve into this shortly, but first let's focus on the changing relations of presence. For the effect of the new paragraph is to perform a subtle shift. It 'reminds' us what is absent from the formalism, but this is a double effect. First it 'reminds' us that there is no reference to 'the real world', to what 'actually happens' (as opposed to what might, perhaps, happen). But second, it also inserts that absent 'real world' into the formalism, which means that after the new paragraph the real world, is, as it were, both present and absent from the formalism, and that the formalism has started to acquire extra weight. It has started to acquire this weight in the impossible interference between absence and presence.

This, then, will be my definition of heterogeneity, heterogeneity in design, and heterogeneity elsewhere. I will say that heterogeneity is an oscillation between absence and presence. It is about the way in which whatever is not there is also there, but also how that which is there is also not there. Heterogeneity, then, is about the differences that reside in connection and disconnection or, more precisely, it is about the ambivalent distributions entailed in dis/connection. Which means that simplicity not only creates absence but it also depends on presence. Hence the term above: 'heterogeneity/simplicity'.

Now we are in a position to ask whether there other forms of absence/presence, other heterogeneities.

## Fourth Story

If we stay with the aircrew a little longer and search through the pile of documents we find this:

> 'The state of the pilots is variously described as "tired", "bathed in sweat", "weakness in limbs", "headache". The main factors causing fatigue appear to be several. There are oscillations in the higher frequencies to which various portions of the human anatomy respond ... , moderate impacts which continually jar the pilot and throw him about, and occasional large gusts which frighten him by giving the aircraft a violent movement. In addition the pilot had the strain of carrying on with his job, and the worry whether the aircraft structure would stand up to the treatment.'[6]

This paragraph is taken from an internal English Electric memorandum

Observing next that the pilots are ‘near the limit of their endurance’, it continues by noting that: ‘The navigator, who has his eyes on his instruments, will be more prone to sickness than the pilot who looks at the horizon. At the same time he will be trying to extract precise information from a variety of electronic equipment requiring fine adjustments to be made by hand.’[7]

**Heterogeneity/materiality**

Here we have a second form of absence. This isn’t a matter of simplicity – or if it is, then it is a new form of simplicity, for this is material absence. Removed from the flat space occupied by the formalism, we find ourselves in the sweating world of the aircrew. We discover pilots who flew their creaking aircraft too low, pilots who worried about whether the wings would break off, pilots who were thrown about their cockpits, pilots who climbed shaking from their aircraft at the end of these flights.

If we are imaginative then perhaps we can smell the fear, feel the sweat on the bodies, the taste of vomit. For this is another set of presences, another set of relations, another syntax, another set of differences – different presences that are absent from the space of algebra.

The corporeal or, if we include the aircraft, the corporal-and-the-technological – these are absent from the space of the page, from the formalism about ‘G’, gust response. This is the absence of a form of materiality. In the way they write the P17A brochure, there is no room for vomit, it does not fit. There is no room for sweat in formalisms. In the documents that are sent to the government ministries there isn’t enough space for Meteor aircraft, so they are removed, and not simply because there isn’t enough room, but also, or more, because they are materials that do not perform themselves in the differences of the page, within a logic performed in algebraic difference.

Yet, these are absences which are also present, for G is there on the page. Gust response is fixed not by the other parameters that occur in the formalism (though these are fixed in their relations with one another), but rather in a set of relations of absence/presence to do with the suffering of aircrew. ‘By comparing several aircraft, of known characteristics, which have been flown in low altitude turbulence,’ (I quote the sentence again) ‘it is possible to decide a maximum value for this parameter which will ensure a comfortable flight.’ This is a parameter to do

with comfort of particular aircrew, comfort that will allow them to perform the task of piloting the aircraft efficiently, properly.

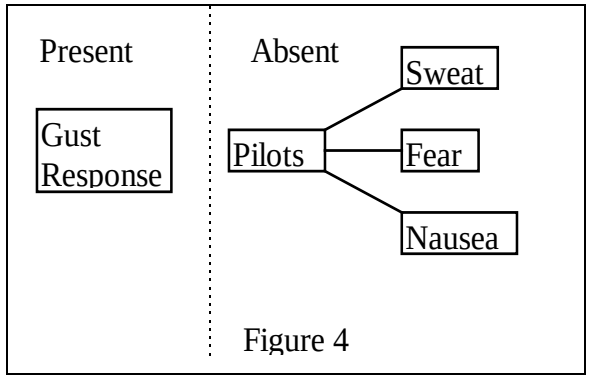

Figure 4

Absence/presence, the absence of materiality which is also a presence – no doubt this is what those who write actor-network studies intend when they talk of 'translation' and 'chains of translation'[8]. And this is a second oscillation in the distributions of heterogeneity: the absent presence of materiality, the Otherness of materials that don't fit in, but also do.

**Fifth Story**

Before I go on with this story of what is absent – about the absence, for instance, of fear – I need to go back to the formalism to understand what is happening to G and to forget, for the moment, the crew, 'If the gust response parameter, G, is fixed to give a certain response level, and the operational Mach number and the aircraft weight are also fixed, then from (1) it is clear that $a_t.S$ becomes constant' What is happening here? Let's deal with formalism first.

If G (gust response), M (speed) and W (weight) are fixed then this means that the only terms which still have freedom to move are $a_t$ and S. It's easier to see what's going on if we re-write the first expression

$$G = \frac{M.a_t}{W/S} \quad (1)$$

as

$$G = \frac{M.a_t.S}{W} \quad (2)$$

But if G, S and W are now fixed then equation (2) reveals that $a_t$ multiplied by S is (now going to be) a constant. When one goes up the other

goes down. It's a nice simplification: speed is inversely correlated to transonic lift slope.

But what of W and M, weight and speed? How come these have been fixed? Let's think first about speed. The previous page of the English Electric Brochure tells us that: 'The essential design compromise implied by O.R.339 is between high speed flight at low level, and operation from short airfields. The intermediate choice between a high-wing loading with a low aspect ratio to minimise gust response, and a large wing area assisted by high lift devices to provide plenty of lift at low speeds, must be resolved.'[9] Here there are a lot more complications, but let's focus on the phrase 'high speed at low level'. Where has this come from? The answer is in 'O.R. 339' which is an Air Ministry document, an Operational Requirement written by officers of the Air Force and telling a story about what a new aircraft is supposed to do. Part of paragraph 10 of O.R.339 runs as follows: 'In order to minimise the effect of enemy defences, primary emphasis will be given to penetration to, and escape from, the target at low altitude.'[10] And part of paragraph 16 reads: 'The penetration speed is to be in excess of M = 0.9 at sea level, with an ability to make a short burst at supersonic speed.'[11]

So speed, M, is fixed '[i]n order to minimise the effect of enemy defences.' But if we push the paper chase one stage further we can ask: who is the 'enemy'? and what are its 'defences'?

Here is the opening paragraph of O.R.339: 'By 1965 a new aircraft will be required by the Royal Air Force for tactical strike and reconnaissance operations in limited war using nuclear and conventional weapons. Such an aircraft will enable the Royal Air Force to continue to make an effective contribution to the strength of SACEUR's shield forces, as well as to our other regional pacts.'[12] SACEUR: this is an acronym for Supreme Allied Commander Europe which tells us, as if we didn't already know, that we have encountered another looming absence/ presence: 'We shall wish to consider whether there is a requirement for a low level weapon, either manned or unmanned, in case the Russian defences become effective against high flying aircraft and ballistic missiles.'[13]

Here it is at last, made present, not in O.R.339 but in the correspondence of government ministers. Taking the paper chase one step further into a background document to O.R.339 which describes the earlier Canberra, we at last begin to learn about the likely defences of the Russian

enemy: ‘The Canberras, operated strictly at a low level, may continue to be effective until the enemy develops an efficient low level surface to air guided weapon.’[14] If an attacking plane is to get away from a defensive, surface to air, guided weapon then it need to fly fast (‘high penetration speed’) and very low – but the Canberra can’t do this.

**Heterogeneity/Otherness**

This chain of differences is long-winded, ramifying endlessly and growing many branches. But we don’t need to look into all of its ramifications. Retracing one line will do, one set of dis/connections.

Gust response, G, was fixed in a relation of material heterogeneity, the absence/presence of the sweating pilots. And M, Mach number was also fixed because O.R. 339 said sought to minimise the effect of enemy defences. In the final set of dis/connections the enemy turned out to be ‘the Russians’, and the defences ‘an efficient low level surface to air guided weapon.’ So ‘fear’ and ‘the Russians’ were also within the formalism, not simply outside it.

None of this is empirically extraordinary. In tracing this chain we’re not learning anything startling about the design of the P17A. But I think we’ve learned something more about heterogeneity. We’ve learned that the enemy is within, that it is within the design, within the formalism. And the chain spells out the way – one of the ways – in which the enemy has been incorporated or assimilated.

This is another form of heterogeneity, another oscillation in differences that are both absent and present. For the enemy and its surface to air guided weapons are a part of the formalism, a part of the wing design, rigorously present. At the same time, like the extended formalism, and the bodies of the pilots, they are just as rigorously absent. So the argument is that this is a third form of heterogeneity; another version of the alternation of absence/presence, the heterogeneity of tellable Otherness. The enemy excluded, the foe that is necessary, necessarily included, necessarily a part of the centre, necessarily other

‘The Other’ is a threat. The Air Force Officers who write Operational Requirements talk in just those terms, speaking of ‘the threat’. This means that ‘the Russians and their surface to air guided weapons’ are like Edward Said’s orientials[15]. They are necessary to the West, to its making

of itself because they are dangerous, different, antithetical. They play a similar ambivalent role, for they are indeed a threat, a danger, something apart and something to be kept apart which deserve to be forbidden, excluded, kept at the periphery. Or, in the language of defence, they deserve 'interdiction'. So Otherness is a dangerous absence, but at the same time it is a promise, a seduction, a necessity, an incorporation, a need incorporated in its absence into the semiotics of presence. It is incorporated, for instance, into speed, M, and into the formalism linking gust response, G, to M, for without this incorporation M might take any value, the wing of the P17A might take a different shape, and the RAF need for 'a new aircraft' would also look different or perhaps disappear altogether.

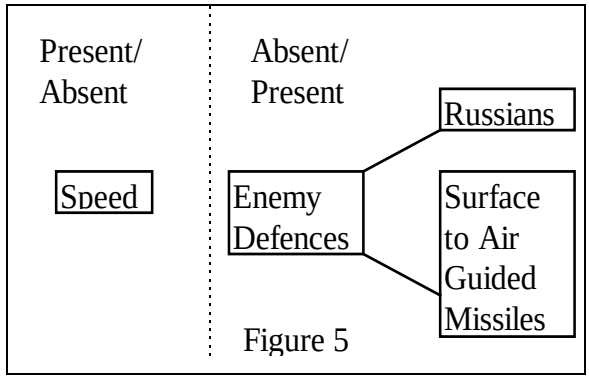

Figure 5

Heterogeneity/Otherness is a third form of heterogeneity. It says that the forbidden, the abhorrent, sometimes even the unspeakable, is both present in and absent from whatever is being done, designed, or said[16]. Fear is distributed as an absent presence in the centre, in the formalism.

## Sixth Story

Let's go back to the fixing of parameters. Remember: 'If the gust response parameter, G, is fixed to give a certain response level, and the operational Mach number and the aircraft weight are also fixed, then from (1) it is clear that $a_t$.S becomes constant' So G and M are fixed but how has weight, W, been fixed? Here's English Electric's Brochure again:

> 'It is desirable both from the point of view of development time and cost, that a proposed aircraft to any given specification should be as small as possible. For any project study the optimum size of aircraft is obtained by iteration during the initial design stages. The size of airc-

> raft which emerges from this iteration process is a function of many variables. Wing area is determined by performance and aerodynamic requirements. Fuselage size is a function of engine size and the type of installation, volume of equipment, fuel and payload, aerodynamic stability requirements and the assumed percentages of the internal volume of the aircraft which can be utilised.'[17]

So there are many variables, too many to magnify. Let me stick with engines.

Aircraft size (and therefore weight) isn't simply a matter of the 'size and type of installation' but is also, and even more immediately, a function of the number of engines. Here is O.R. 339 again: 'The Air Staff require the aircraft design to incorporate two engines.'[18] But why two engines? The English Electric brochure offers an ansert in the course of writing about another aircraft, the P.1B.

> 'Abandonment of twin engines would be the only other way of achieving a smaller aircraft and this also involves a large reduction in the sortie pattern. This arrangement has not however been considered, due to the overwhelming pilot preference of a twin-engined arrangement even in the P.1B. This is because of the very high accident rate of supersonic aircraft following total engine failure, due to their very high rate of descent and the limitations of emergency power control systems. The argument for two engines in the present case is reinforced by the need to operate several times further from base than the P.1B and for a substantial time at low altitude where the glide capability would be much reduced.'[19]

The pilots are back again. This time they are not being frightened by oscillation or being made nauseous, but they are worrying about another difference that is absent but present, for the worry is that supersonic aircraft are more likely to crash, and the O.R.339 aircraft has to travel a long way from home.

But there are other possible differences. Here is Vickers Armstrong. Vickers was a competitor of English Electric which had submitted its own design, the Type 571. One of these designs was for a single engined aircraft:

> 'From the very beginning of our study of the G.O.R we believed that if this project was to move forward into the realm of reality – or perhaps

> more aptly the realm of practical politics – it was essential that the cost of the whole project should be kept down to a minimum whilst fully meeting the requirement. This led us towards the small aircraft which, by concentrating the development effort on the equipment offers the most economical solution as well as showing advantages from a purely technical standpoint.'[20]

And again: 'Overseas sales. The cheaper this aircraft is, both in first cost and operating cost, the wider it's [sic] overeas sales potential will be. This would seem to favour the single engine system.'[21] The argument was that a small aircraft would sell better; be more lethal per £ spent, and might even be attractive to the Royal Navy since it might fit on their aircraft carriers.[22]

**Heterogeneity/non-coherence**

Aircraft safety, pilot worry, the need to fly far from base, this was one set of relations, one set of differences, one set of considerations that tended to fix W at a higher value, make the aircraft heavier. Cost, cost-effective lethality, naval use, practical politics, sales, this is a second set of relations, of differences, of considerations that tend to fix W at a lower value and so make the aircraft lighter.

So there are two sets of connections, two sets of relations of difference. This is old territory for technoscience studies. It's a controversy. The Air Ministry is going to disagree with Vickers and stick with its large aircraft. 'The reply by D.F.S. to D.O.R.(A)'s request for a study on the single versus twin engined aircraft was received 16th July. It showed fairly conclusively that the twin engined configuration is the less costly in accidents.....'[23] But if it is a controversy, it is also another form of absence/ presence – for controversy and disagreement are absent from W. They are absent from the formalism – there is no room for controversy in formalisms. There is space for trade-offs, reciprocal relations, all kinds of subtle differences and distributions yes, but controversies no, and non-coherences not at all.

If the arguments about the size of the aircraft, about W, about the number of engines it should carry, are a form of controversy, they are also an expression of non-coherence, dispersal, and lack of connection.

This is because the Air Ministry is talking about one thing while Vickers about another:

> '... we must be perfectly clear as to what is the principal objective of the design. It is to produce a tactical strike system for the use of the Royal Air Force in a limited war environment, or a 'warm peace' environment, and should thus be aimed at providing the maximum strike potential for a given amount of national effort. It is not – emphatically not in my view – to produce a vehicle to enable the Royal Air Force to carry out a given amount of peace-time flying for a minimum accident rate.'[24]

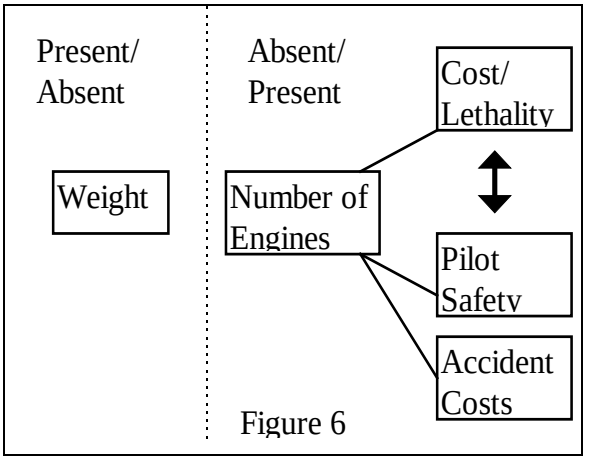

Figure 6

Vickers is talking about cost/lethality, and the Air Ministry about accident costs. This is a dialogue of the partially deaf. It is also a dialogue in which the Ministry decides – in which it 'has' the power. But there is something else, a point to do with absence/presence, about the absence/presence of non/coherence. What is present encompasses, embodies, connects, makes links that are absent. Except that they aren't connections at all because they aren't coherent, and they aren't joined up into something consistent. Except that they are nevertheless brought together, in their non-coherence, into what is present. (Present) coherence/ (absent) non-coherence, like jokes, or the performance of jokes in Freud's understanding, non-coherence or interference is a fifth version of heterogeneity.[25]

## Seventh Story

Gust response, speed and weight are fixed, so we are left with $a_t$, lift slope, the slope of the curve that tracks variations in lift against changes in angle of attack and the hope that it will be flat. But there is more. For instance, the stories are about transonic flight: how the wing will behave at roughly

the speed of sound. But there are other questions. For example, how it will act at low speeds. So here's another complication, one that I earlier chose to ignore. This is the quotation again, from the English Electric Brochure: 'The essential design compromise implied by O.R.339 is between high speed flight at low level, and operation from short airfields. The intermediate choice between a high-wing loading with a low aspect ratio to minimise gust response, and a large wing area assisted by high lift devices to provide plenty of lift at low speeds, must be resolved.'[26]

So gust response is important, but so too is take off – which means the need for plenty of lift at low speeds. The Brochure says:

> 'Another convenient parameter is one which gives an indication of the relative response to gusts while achieving a given take-off distance. This may be expressed as P say, where
>
> $$P = \left( \frac{a_t}{C_{L_F}} \right) \quad (3)$$
>
> where $C_{L_F}$ is the maximum trimmed $C_L$, flaps down, in touch-down attitude. P must be a minimum for good design.'[27]

We've met these terms before. A reminder:

- $C_L$ is lift coefficient, roughly the lifting force of a wing: here, the lifting force of the wing as the plane comes into land with its flaps down.
- And $a_t$ is lift curve slope, change in lift against change in angle of attack.

This means that P quantifies a hybrid relationship, the hope, that it is possible to find a wing with low transonic gust response and high lift at landing – but how to find a wing of the right 'planform' or shape? The Brochure continues: 'In the absence of comprehensive data on the effects of flaps on low aspect ratio wings, a comparison replacing $C_{L_F}$ by $C_{Lmax}$ indicated that delta wings were superior to trapezoidal and swept wings.'[28] The terms here are as follows:

- $C_{Lmax}$ is the aerodynamicist's way of talking of maximum lift.
- low aspect ratio wings (a reminder) are wings that are short in relation to their area.

- delta wings are triangular, like those of a paper dart.
- and a trapezoidal wing is shaped like a trapezium. That is, though its tip is parallel to its root, the leading and trailing edges converge towards that tip.

The paragraph continues to talk about planform:

> 'Since it was thought possible that by using leading edge flaps on trapezoidal wings, higher values of $C_{L_F}$ might be obtained than those from delta wings, wind tunnel tests were carried out using a trapezoidal wing-body combination. In the event, these tests confirmed that the delta gave higher values of $C_{L_F}$. The delta planform was also expected to have better transonic characteristics, and again high speed tests in our 18" tunnel on a family of aspect ratio = 2 planforms confirmed the unsatisfactory characteristics of trapezoidal wings, with sudden large aerodynamic centre movements at transonic speeds. This confirmed the choice of the delta planform.'[29]

To understand this we need to know about aerodynamic centres. As it moves through the air a wing lifts, but it does so by differing amounts in different parts of the wing. However, it's useful to sum the effect of all these separate parts to create something called the 'aerodynamic centre'. Roughly speaking this is the place in the wing where the changes in overall lift occur as it flies faster or slower or its angle of attack changes. Above stalling speed the location of the aerodynamic centre doesn't shift much: for most wings it is about one quarter back from the leading edge at subsonic speeds. But as the plane flies faster, at around the speed of sound the aerodynamic centre tends to move backwards. This isn't a disaster unless it moves quickly and jerkily, in which case the aircraft can be difficult to control – which would take us back to pilot sweat and fear.

So the English Electric engineers were looking at two things. One was aerodynamic centre. Here the trapezoidal wing was a problem. The movement of the aerodynamic centre was 'sudden' and 'large', while the delta wing was better behaved. The second was $C_{Lmax}$ (max, here, means maximum lift). Here there was a surprise: the delta wing was better again. On both counts the trapezoidal wing came off worse.

**Heterogeneity/deferral**

There are two sets of relations: the link between planform, the shape of the wing, and $C_{L_F}$; and the link between planform and aerodynamic centre. The delta wing is better – better, that is, in the wind tunnel.

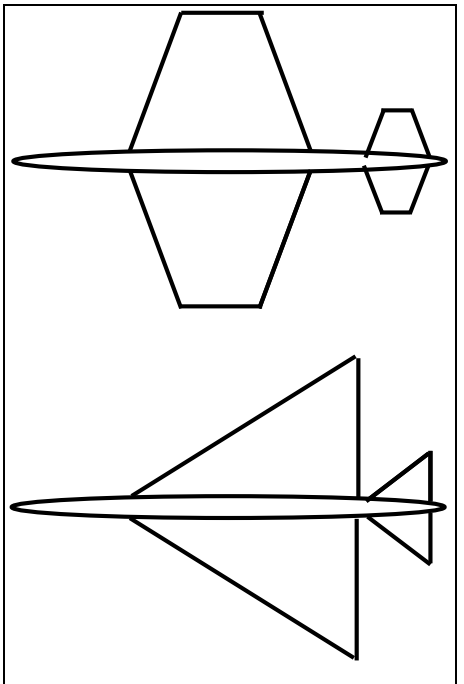

Figure 7: Trapezoidal and Delta Wings

The wind tunnel – this is another instance of heterogeneity/materiality, of distribution between absence and presence. On the one hand there are the flat surfaces of the drawing office which work to pull everything together, to centre it; and on the other there are the three-dimensional models, materials, and measurements, of the wind tunnel. So the wind tunnel is absent from the formalisms of the design office and yet they are present too. But there is something more, something more subtle about the differences that emerge in that distribution. This is the fact that they are produced in movement, in a continuing process of displacement, in a continuing displacement between materials and sites.

Perhaps one way of saying this is that it isn't possible to 'sum up' the wing in the design office. The representation that appears in the design

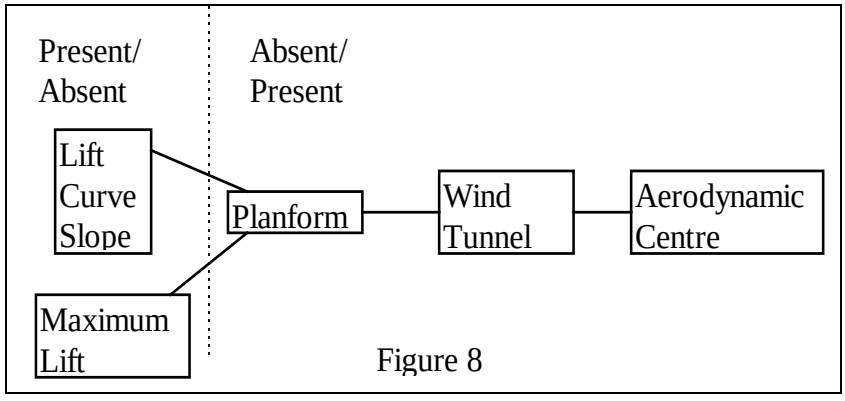


Figure 8

office, the sets of formalisms and the drawings, is incomplete, unfinished. It is not centred, it is not drawn together, because it needs the wind tunnel. It needs the differences that will be generated in the move to the wind tunnel. But so, too, is the version of the wing that appears here. It is also incomplete and needs further attention, further attention by the design office, by stress engineers, machinists, metallurgists – and later, by maintenance engineers and mechanics.

This is another ambivalence of absence/presence. This is because the wing is present, all there, drawn out. But those lines also embody absence, the absent/presence of differences that are deferred, of relations that are still to come and have still to be made – relations which are not present, are not now. So the distributions here, the absent/presences are differences in movement, involving displacement through time in what Jacques Derrida calls différance. They involve an oscillatory distribution between the present/now and the absent/future, or the absent/now and the present/future. They work in the heterogeneous interferences of time, in what we might think of as heterogeneity/deferral.[30]

**Eighth Story**

In English Electric's summary Brochure there is a section at the beginning called 'History'. Here's part of the first paragraph: 'Several widely-differing designs for a Canberra replacement aircraft were studied at Warton towards the end of 1956, and, by early 1957, calculations and wind tunnel tests had shown the optimum design to be an aircraft resembling the P.17 configuration. The merits of this configuration were confirmed by further tests, and the design was found to meet G.O.R 339 requirements as these became known.[31] This paragraph is accompanied by three drawings of the P17A which give an overall view of its geometry (see Figure 9):

The full Brochure offers a more abstract account: 'The design process of a modern aircraft, especially a versatile one, could be summarised as obtaining the best combination of a large number of variables each one of which reacts on many of the others. The final product must meet each of its requirements roughly in proportion to the emphasis placed on the relevant role.'[32]

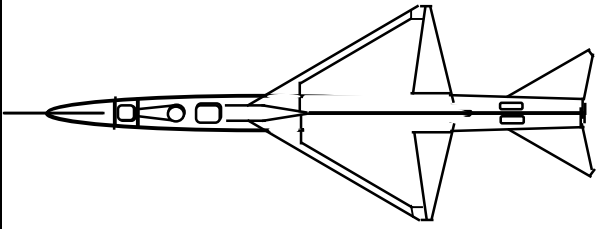

Figure 9: Plan of English Electric P17A

This is a sentiment which echoes those of a government white paper.

> 'An aircraft must be treated not merely as a flying machine but as a complete "weapons system". This phrase means the combination of airframe and engine, the armament needed to enable the aircraft to strike at its target, the radio by which the pilot is guided to action or home to base, the radar with which he locates his target and aims his weapons, and all the oxygen, cooling and other equipment which ensure the safety and efficiency of the crew. Since the failure of any one link could make a weapons system ineffective, the ideal would be that complete responsibility for co-ordinating the various components of the system should rest with one individual, the designer of the aircraft. Experience has shown that this is not completely attainable, but it is the intention to move in this direction as far as practical considerations allow.'[33]

## The Architectures of Heterogeneity

We move, then, from the wing back to design, to design, as they say, 'in general'. Design is heterogeneous, this is the argument. It enacts distributions in the form of an oscillation between absence and presence, and oscillation is one of the conditions of its possibility. This means that from the point of view of the centre it is ambivalent and incomplete. It also means that it embodies and expresses a set of tensions between what is

present on the one hand, and what is absent but also present on the other. Simplicity, materiality, Otherness, in/coherence and deferral, these are the tensions and ambivalences that I have listed . No doubt there are others, many others, and no doubt they are heterogeneous too, these distributions[34]. Heterogeneity is just that: heterogeneous.

This is the point of my argument. I want to recover the ontological heterogeneity of this term, heterogeneity. I want to understand the tensions that are made in design, in centering, in drawing things together. This is difficult, itself a process full of tension. For the risk is that when we talk of it we also lose the oscillatory and unassimilable character of heterogeneity: 'I am arguing ... that the stability and form of artifacts should be seen as a function of the interaction of heterogeneous elements as these are shaped and assimilated into a network'[35]

This comes from an article that I wrote in 1987. Here heterogeneity had to do with what I am now calling heterogeneity/materiality. The concern was with system-building: the manipulation of all kinds of materials, technical and human. No doubt this is fine, but it also needs to be nuanced. We need, or so I am suggesting, to avoid the flattening effect of imagining that there is, on the one hand, a great designer, a heterogeneous engineer, and on the other a set of materially heterogeneous bits and pieces. Instead we need to hold onto the idea that the agent – the 'actor' of the 'actor-network' – is an agent, a centre, a planner, a designer, only to the extent that matters are <u>also</u> decentered, unplanned, undesigned. That, to put it more strongly, to make a centre is to be made by a non-centre, a distribution of the conditions of possibility that is both present and not present.

These, then, are tropes with which we might play in technoscience studies of complexity. For the differences are small. There are many narratives with a centre of one kind or another in technoscience studies and in large technological systems[36]. Electricity systems, weapons systems, technoscience systems, the performances are similar and the resonances between these 1987 words from technoscience studies and those penned by the anonymous author of the 1955 government policy statement about weapons systems cited above are more than coincidental.

But why this similarity? Why this common cultural bias? Here is an hypothesis. The notion of 'heterogeneous engineering' may be understood in two ways. It may be treated as a way of thinking about oscilla-

tion, absence/presence, uncertainty, and the necessary Otherness that comes with the project of centering. In short, it may be treated as a feature or an aspect of complexity as this is understood by the contributors to this volume. Alternatively, it may be used to describe and perform an architecture of modernism[37]. No doubt there are different versions of this 'modern project'. No doubt they do different things. But, to put it too quickly, perhaps we might say of this that it is a way of being that seeks to improve the world, to engineer it, to build a better society by knowing, by gathering knowledge together, and then by deploying it in the attempt to order relations in the best possible way. This is an architecture that seeks to impose a specific and optimum distribution on its materials, human and otherwise.

The second version of 'heterogeneous engineering' resonates with the benevolent and centering intention of this modernism. It catches something important about each of the 'modernist' quotations above: the historical talk of the aircraft design and its 'merits'; the 'best combination of variables' cited in the English Electric statement of design philosophy; Vickers' systems talk with its tradeoffs between cost and lethality; and the 'combination' of elements mentioned in the government statement about weapons systems. In each it catches the utopian need to deal in different kinds of materials, technical and social, to centre them, to handle them, to manage them. It does it with the characteristic modernist lack of concern with things in themselves – with, for instance, the distinction between human and non-human – for the perfect society involves both human and technical innovation. In each it catches the concern with simplification; with bringing materials together to optimise the outcome. It catches, that is, the need, the desire, to combine them together at a special privileged place, that of the designer. In each it catches the 'semiotic' impulse that underpins the combination of somewhat pliable bits and pieces: the idea that components are a more or less malleable effect of a set of relations of difference; a set of relations that can be engineered to produce a better world. Perhaps, too, it also catches in each of these citations an acknowledgement of deferral. The deferral implied in the process of experiment, the trial and error, the iteration towards utopia.

The 'modernist' version of 'heterogeneous engineering' plays on all these notions. It resonates with them. But it misses the complexities of heterogeneity. It misses those places that don't fit so well with the control

impulse, that have forgotten that even the control impulse, the possibility of centering, is made by distribution into heterogeneity. This means that it doesn't catch the heterogeneities of non-coherence, the fact that things don't add up, the oscillations that make the mirage of the perfect centre.

What happens if the heterogeneous distribution and its interferences are reclaimed from the flattening that comes with the modern project? If they are detached from its utopianism, removed from the concern to centre? For as it is, heterogeneity, when it is recognised at all, is only recognised from a place of homogeneity, a design/control place, where whatever does not conform becomes a technical obstacle, an irritant, something to be managed, limited and controlled.

Are there alternatives? What might the alternatives be? Perhaps we might acknowledge that the conditions of possibility are lumpy and different, multiple in character. Perhaps we might remember that heterogeneity is, indeed, heterogeneous, an expression of complexity. Perhaps we might imagine that absence/presence comes in indefinitely many forms, and then investigate some of those forms, and live with them. But what would happen if the ambivalences of absence/presence were no longer treated as something to be commanded and constrained, to be controlled from a single centre? For it may be that there are ways, various ways, of welcoming their alterity. Not in the form of a large project which will finally, at the end of the day, at the end of history, improve society. Not as yet another grandiose utopia for ordering the social, for remaking it in a better way. But neither in the form of the resignation of quietism. Such are the questions that start to flow if we once recognise the heterogeneity of heterogeneity.[38]

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[*] I am grateful to: the Nuffield Foundation for Fellowship support which made possible the collection of data; British Aerospace, the North West Heritage Group of British Aerospace and the Brooklands Museum for permission to explore and cite British Aircraft Corporation Files; to Brita Brenna, Michel Callon, Claudia Castañeda, Bob Cooper, Mark Elam, Kevin Hetherington, Bruno Latour, Ivan da Costa Marques, Ingunn Moser, Bernike Pasveer, Vicky Singleton, Marilyn Strathern, Sharon Traweek and Helen Verran for their intellectual support; and in particular to Annemarie Mol for a sustaining collaboration and friendship over nearly a decade.

[1] The figures are taken from English Electric (1959). This was a short brochure produced by English Electric for senior RAF and government personnel. The figures quoted differ marginally from the full length brochure (English Electric/Short Bros.: (1958)) though the differences do not affect the argument.

[2] English Electric/Short Bros.: (1958: 2.1.9.)
[3] The point is developed by Marilyn Strathern in her (1991).
[4] See, for instance, Callon (1991).
[5] English Electric/Short Bros.: (1958: 2.1.9.)
[6] See English Electric (1957).
[7] See English Electric (1957).
[8] See, for instance Latour (1993) and Callon (1995).
[9] English Electric/Short Bros.: (1958: 2.1.8.)
[10] Air Ministry (1958).
[11] Air Ministry (1958).
[12] Air Ministry (1958).
[13] AIR8/2167 (1957).
[14] AIR8/2014 (1956).
[15] See Said (1991).
[16] The argument is developed in technoscience studies by Donna Haraway (1991a). A further point: like others who have written in STS, I should observe that the analysis is impartial with respect to (what is sometimes called) truth and falsity. I am neither saying that the Russians 'were' or 'were not' an enemy.
[17] English Electric/Short Bros.: (1958: 2.1.8.)
[18] Air Ministry (1958), paragraph 9.
[19] English Electric/Short Bros.: (1958: 1.S.6.) Consider also this: 'Only the most phlegmatic and unimaginative individual can fail to take a keen interest in the running of his only engine when he is a few hundred miles from the nearest land or the nearest area of population or line of communication.' (Vickers Armstrong: 1958a).
[20] Vickers Armstrong (1958b:2 ). This is a short glossy version of the Vickers Armstrong submission in response to G.O.R. 339.
[21] G.O.R. 339, Vickers Armstrong, letter from J.K.Quill to H.H.Gardner, 1st July, 1958, page 3.
[22] Vickers Armstrong (1958c:2-3).
[23] AIR 8/2196, para 43.
[24] Vickers Armstrong (1958a: 1).
[25] The importance of non-coherence for the cohesion of the UK cervical smear programme is explored by Vicky Singleton. See Singleton and Michael (1993)
[26] English Electric/Short Bros.: (1958: 2.1.8.).
[27] English Electric/Short Bros.: (1958: 2.1.9.).
[28] English Electric/Short Bros.: (1958: 2.1.9.)
[29] English Electric/Short Bros.: (1958: 2.1.9.).
[30] See Jacques Derrida (1978) and also Frederic Jameson's (1991:38-45) discussion of movement in representation where he writes about the Westin Bonaventure Hotel.
[31] English Electric (1959).
[32] English Electric/Short Bros.: (1958: 2.1.8.).
[33] Her Majesty's Stationery Office (1955:9).
[34] For discussion of tension in a related context see Robert Cooper and John Law (1995) and John Law (1998).
[35] Law (1987: 113).
[36] See Thomas P. Hughes (1983), Michel Callon (1986) and Bruno Latour (1988).
[37] Zygmunt Bauman (1989).
[38] As, for instance, is argued in Gilles Deleuze and Félix Guattari (1988).

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