WORKING IN HARMONY: AN EXAMINATION OF COMPUTER TECHNOLOGY IN AIR TRAFFIC CONTROL

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ABSTRACT

This paper will examine how computers support - and sometimes hinder - cooperative working. It will be argued that the design - and any attempt to re-design or re-specify - computerised information resources has to take into account the social organisational setting of cooperative work. Failure to do so may lead to developments that have little or no practical benefits, and may undermine the harmonious functioning of working groups. The argument will be illustrated by reference to a computerised enhancement of Air Traffic Control technology called 'RD3'. Data for the paper was collected during a joint SERC-ESRC research project into Social Aspects of the Automation of Air Traffic Control. Research methods included observation of sector team work in situ; extensive interviewing of London Air Traffic Control Centre operations and management personnel; and transcriptions of audio tapes of sector team activities.

I. INTRODUCTION

The notion that computer technology should be developed to enhance cooperative aspects of work seems to us a misnomer. For it implies that the use of computers to date has been to enhance work that is not cooperative. It is hard to imagine any work that does not involve some kind of cooperation. If any lesson is to be learnt from the emergence of capitalism, it is not that conflict between individuals is endemic, but that every individual is inextricably tied up with the productve practices of every one else: capitalism is nothing if not social, as is, in fact any economic system. This is, of course overstating the case; but consider, even within a single firm it is difficult to conceive of any individual who is not working in some cooperation with others. Consequently, even though a computer system may provide information for only one individual, what is done with that information, its social use, is intrinsically tied up with the cooperative aspects of work organisation. This is not to suggest of course, that the role of computer systems in work does not vary, clearly some systems will have a more important role in cooperative aspects of work. But it does draw attention to the fact that the adequacy of any computer system, even the most simple, can only be assessed not by its extent, speed of calculation, ease of access and so on, but insofar as it 'resonates' - though we recognise that this is an imprecise word, this imprecision itself reflecting or pointing to the 'just what' of the problem in this case - with the work that is required.

This paper will illustrate this argument with reference to a system in air traffic control (ATC) known as RD3, which, although providing more enhanced information resources, was antithetical to the work requirements of air traffic controllers and their support teams. Although the system was not ostensibly designed as a cooperative working practices computer support, it nonetheless affected the cooperative aspects of work. This lead to the unwillingness of controlling personnel to use the system. The lesson we wish to draw then, is that any computer design must take full account of the social organisation of work. The notion of computer supported cooperative working systems is a misnomer to the extent that it implies that computer systems have ever done anything else. We argue that the notion of cooperative working in the context of computer systems is at best a promising metaphor, one which needs to understood by bearing in mind the origin of its home: namely cooperation as a sometime feature of social interaction.

1.1 TECHNOLOGICAL DEVELOPMENT IN ATC

ATC is a technologically rich environment which has, over the years, incorporated many of the innovations in radio communication, radars, and computing. Much of the work of controlling requires the use of complex and sophisticated machines. These provide the resources for controlling decisions, and connect the operational decisions of the controller with aircraft and fellow controllers. The technological richness is reflected in the large research and development support maintained by the CAA and other organisations dealing with both the technical and the human aspects of ATC.

In the 1970's in the UK, the USA, and elsewhere, a number of ATC systems concepts were explored as possibilities for the future shape of ATC.

For example, the Royal Signals and Research Establishment (RSRE), involved in systems research and design for the CAA for nearly 20 years, proposed two concepts. The earlier, Computer Assisted Approach Sequencing (CAAS) was developed to assist ATC in the intermediate and final approach areas for Heathrow as a means of increasing its capacity. The system got as far as feasibility trials but was abandoned soon after, although by that time it was clear that considerable revision would have been required (Crawley, Spurgeon and Whitfield, 1980). The system offered computer generated decision making concerning the required flight path that an aircraft on intermediate approach should follow so that it arrived at the landing threshold at the optimum distance behind a preceding aircraft. Despite its abandonment, what was clear was that such a system would require human controllers to maintain active involvement since the computer would be unable to handle all situations adequately (Fearn, 1975).

More recently, the RSRE developed Interactive Conflict Resolution (ICR) which used the computer in a much more supportive role in decision making than CAAS and, in this respect, was much more a 'computer assistant' to the human controller. ICR, developed for *en route* traffic[1], applied trajectory prediction for aircraft for up to 20 minutes ahead. This information could be requested by the controller and, it was argued, help his/her ability to predict future traffic configurations, including possible conflicts, and so 'buy time' for suitable solutions. The controller could also use the system to search for conflicts, again up to 20 minutes ahead, and be automatically warned by the system of such

[1] This is traffic that flies through a sector *en route* for a destination elsewhere. Consequently, the aircraft will not be descending on climbing much but will be taking a fairly straight flight path through the sector. This makes *en route* sector controlling very different from controlling TMA sectors which are for the airspace above busy airports. There controllers have to deal with aircraft rapidly climbing and descending.

possibilities. In interactive mode the controller could also validate a proposed flight path for any possible conflicts (Ball, 1976). Yet, despite the fact that the computer monitored traffic, detected conflicts and had the potential to suggest solutions, the controller was left to make the final decision.

A more general study of automated ATC systems was carried out in the USA under the auspices of the Transportation Systems Centre between 1971 and 1973, and was designed to examine the feasibility of proposed systems that could cope with traffic demands beyond the 1990's. The Advanced Air Traffic Management System (AATMS) was predicated on assumptions about new flight deck, navigational and communications technologies, the most important being an advanced transponder which would send data to the ground in response to interrogation, automatic data links for routine messages between ground and air, and greater freedom for an aircraft to choose its route (Jenney and Lawrence, 1974; Crawley, Spurgeon and Whitfield, 1980). The biggest change proposed by this system was from an airspace centred approach, based on sectorisation, to a traffic centred approach in which aircraft are allocated either to a computer or to a human controller depending on need. Though the human controller would retain overall regulatory and managerial responsibility for critical operational tasks, he/she would have far less involvement with the direct and continuous control of aircraft.

A more modest approach to improving the ATC system for the future was the development of Intermittent Positive Control (IPC), an automated ground-based collision avoidance service for aircraft (McFarland and Horowitz, 1974). The system would act independently of the controller and warn a pilot of proximate traffic and traffic in potential conflict. The controller would also be warned that one of the aircraft under his/her control is in potential conflict.

One of the distinctive features of the concepts such as these is not so much that developments in computer technology make them more than just idle contemplations, but that the total automation of ATC, in the foreseeable future, is not seen as an option[2]. Moreover, the overriding concern of safety, along with the fact that no ATC system can be 'switched off' while fundamental system changes are designed, tested out and learned, means that any automation of ATC would have to follow the standard pattern of innovation, namely, one of incrementalism.

The upshot of these conditions is that any automated system would have to achieve a suitable balance between the human operator and the machine: a principle endorsed by the ICAO in its original guidelines for the automation of ATC (International Labour Organisation, 1972). As a result, 'There seems little doubt ...that the human controller will play a major role in ATC for the foreseeable future, probably well into the next century" (Crawley, Spurgeon and Whitfield, 1980, p. 8).

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[2]Whether it is seen as an unnecessary option, in being extremely costly, or whether uncontemplatable because of doubts about the public acceptability of a totally automated system, is unclear.

1.2 AUTOMATION AND THE CONTROLLER

Of course, there is no doubt that automation, however incremental, would have effects on the work of the controller; a realisation expressed by a concern for the effect on job satisfaction and, through this, operational efficiency. The considered opinion was that it would be unwise to relegate the controller to simply a monitoring function or reduce his/her activities to routine data entry and retrieval within a highly automated system. Morale and efficiency, it was felt, depend upon the excercise of skill, judgement and experience (ATC Systems Committee, 1975)[3]. Hopkin, who interviewed ATCOs during the CAAS trials, realised that automation could have serious effects on the job satisfaction of ATCOs despite the fact that many of them could see its advantages. Many of them, too, felt that they would be reduced to helping the computer rather than receiving assistance from it (Fearn, 1975). Later, Hopkin made the general point that "Automation, when introduced in a man-machine system, entails that the system, and all parts of it, are assessed in machine terms, since no other terms can be used" (Hopkin, 1975).

However, even though automated systems are on the agenda, and under development, the reality is that the pace of technological development in ATC is still very much an incremental and piecemeal one. Nevertheless, this is not to say that issues of job satisfaction, morale, effectiveness, and so forth, are irrelevant, nor that the study of existing controlling work is redundant. For one thing, and as most experts in this field are at pains to stress, for the foreseeable future ATC will be a man-machine affair and devising a suitable 'symbiosis' of these two elements will be crucial (Crawley, Spurgeon and Whitfield, 1980).[4] This is a problem of deciding the 'architecture' of ATC systems; that is, how the tasks should be divided between controllers and computers given that the latter would have some decision-making capacity. One additional constraint on this is that the computer would have to produce solutions that the ATCO would come to in order to sustain a suitable matching of the performance of man and machine. In short, it has become clear that any new system design in ATC will have to incorporate the social dimension of ATC work.

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[3] As Crawley et al (1980) point out, and as many studies have confirmed, the relationship between job satisfaction and worker performance and/or productivity, is neither clear nor consistent. Although job content, as defined in terms of repetitiveness, does show some relation to job satisfaction as does absenteeism and turnover, the multidimensionality of job satisfaction is clearly an important consideration in investigating its effects.

[4] Indeed, much of the ATC organisation sponsored research on the human factor in controlling is predicated on the need for adequate job design in relation to automated systems.

1.3 THE SOCIAL ORGANISATION OF ATC WORK

To date, the kinds of system that have been used, in the UK at least, have tended to reflect rather than systematically enhance, aspects of the social organisation of ATC work. For instance, the present 'mediator' system[5] at London Air Traffic Control Centre (LATCC) generates discrete sets of information for the teams working on each sector 'suite'. Thus the computer calculates, on the basis of variable data like wind speed and weather, the time an aircraft will arrive in a sector and will accordingly print out a Flight Progress Strip (FPS). This strip notifies the team of the aircraft's iminent arrival, its desired destination and path, speed, type and so on. In addition, the computer will 'process' radar data and present on the radar screens only that relevant to a controllers' requirements[6]. But what the sector teams (and the controller as part of these teams) do with the strips and the radar data is entirely up to them. The computer is not involved in decision making about contolling matters. It is simply an elaborate data base.

In the future some of the functions of members of these teams are likely to be replaced by computer systems. One possibility is that a system will be able to enhance the cooperative features of sector team work. So for example, the revisions made by one member of a sector team (we shall describe the sector team shortly) to a Flight Progress strip, relating to agreements made with an adjacent sector, will be done by the computer. Such a system would be assisting rather than reflecting the cooperative and team like aspects of sector control work.

Such enhancements however, would be far from simple: for the social organisation of sector teams is both complex and fragile. This is underlined by the failure of a relatively minor system development at LATCC. This developmet, which we will label RD3[7], is the topic of this paper. Our concern is not so much to decribe the technical specifities of RD3, as to use explanation of its failure as a device to highlight the complexities and fragilities of the social organisation of ATC work.

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[5]The Mediator System was bought in the late 60's for LATCC (known as LATCC Development Step 1). It became fully operational in 1974, and is still the basis of the centre's system some 14 years later [prior to this the system was based on 'primary radar data' and a fairly limited Flight data processing computer system, known as Hermes]. The Mediator System was designed to satisfy the requirements of an entire ATC centre and included furniture (that is, radar screens and frames, known as 'suites'). An IBM 9020D had the potential to combine Radar Data Processing (RDP) and Flight Data Processing (FDP) functions. Ultimately, (under Step 3 of the LATCC plan) a joint FDP-RDP system, based on the IBM, was to be introduced. For a number of reasons this was never attempted.

[6]Thus targets such as large cloud formations, flocks of birds, balloons, parachutists, UFO's (and there are many in the airspace) and so on are deleated from the radar screen leaving it 'clean and tidy'.

[7]The term is used to identify several separate developments. Our use of a single term for these changes is partly to ensure simplicity and partly in accordance with controllers' own usage.

2. THE CASE OF RD3

A key feature in the introduction of any new technology into ATC operations is the attitude and response of controllers themselves. They are the factor in the ATC system which most determines the amount of traffic that can be handled and so they play a key role in the acceptability, or otherwise, of any technological change. Controllers are highly skilled at what they do, carry a great deal of responsibility and exhibit a strong pride in their craft of ordering the airways safely and expeditiously. Further, as a number of studies in various countries have shown, rates of overall job satisfaction among ATCOs is high, especially due to the challenging nature of the work (Grandjean, Witzka and Kretzschmar, 1968; Kennholt and Bergstedt, 1971; Singer and Rutenfraaz, 1971; Smith, 1973; Clark, Quinn and Lacey Scott, 1973). As far as performance is concerned, over the years, despite increasing traffic flows, outdated equipment and increasing pressures to cut costs, the safety record of UK ATCOs is impressive. There has never been a mid-air collision involving British civil ATC since its inception as an organisation.[8] As far as records are able to determine, the UK has the best record in this respect in the world.[9] This strong corporate pride among operational controllers, while leading to a highly motivated and responsible work force, also gives rise to an unwillingness to take technological and other innovations 'on trust'. Systems must be demonstrably safe and trustworthy to controllers, before they are acceptable. As we discovered, cynicism and conservatism toward new technology and operational techniques is a strong element in the occupational culture of controllers despite the fact that they work in a technologically rich environment. This feature also affects management-workforce relations. Yet at the same time, many ATCOs are eager for the 'right kind' of technological enhancement and reorganisation. Many of these factors are illustrated by the controllers' reaction to the RD3 system.

RD3 was a synthesis of, on the one hand, available software and, on the other, new hardware and radar technology and, as such, was not a dramatic change in controllers' technological environment[10]. Nevertheless, as far as management saw it, RD3 offered a number of advantages: the combination of Flight Data Processing (FDP) and Radar Data Prossessing (RDP) will almost certainly form the basis of future ATC technology and RD3 would introduce controllers to its principles; it would dramatically change the type and source of information available to controllers and so enhance the performance of ATCOs; and, since it was to be introduced on existing furniture, controllers would be able to switch in and out of the system as

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[8] On average there are 3 air crashes per week in the UK, none of them attributal to ATC error. Source: Danger and Distress Unit, LATCC.

[9] A number of countries do not supply figures.

[10] To understand RD3 one needs to look at the background to its development. As mentioned, the 'Mediator System', was designed to to create a joint FDP-RDP system, but, for a number of reasons, this was never attempted. RD3 was a halfhearted attempt to emulate some of the perceived benefits of a fully integrated FDP and RDP system. See Hughes et al, 1988; Harper et al; 1989.

preferred using the old and familiar system as a backup[11].

2.1 RD3 IN PRACTICE

There was, therefore, every hope that the system would improve the working environment of controllers and, by making extra information available, ease the expedition of controlling. However, controllers were, at best, indifferent to it and, at worst, positively hostile. It was not, in the main, seen as its designers intended, that is, as a forerunner of future developments using present technology, but as an innovation that was irrelevant, badly conceived and difficult to operate. A survey NATS conducted some months after the introduction of RD3 presented a dismal picture. Less than 10% of controllers returned the questionnaire and nearly all of these were controllers who preferred not to use the system. Our own interviews and conversations with controllers confirmed the problems mentioned in the survey. Amognst other things, complaints related to the difficulty of accessing information displays, the irrelevance of the information thus provided, problems with mosaic radar data processing and the increased likelihood of conflicts using it; the unreliability of the technology, its confusing layout and time-consuming operation, and the general difficulties of using RD3 within a Mediator system. The few advantages noted referred to vector lines and the Direct Routing facility. In sum, the system was held to be untrustworthy, so much so that one watch (there are 5 operational watches at LATCC) temporarily banned its use.

The story of the reception of RD3 by controllers is instructive since it told us a great deal about the character of controlling work and the occupational culture in which it is embedded. In particular, it highlighted two issues. First, an important attitude which underpins controllers' effective work, and one that is difficult to overestimate, namely, the ability to assume that the technology can be trusted. Second, it drew attention to the nature of the cooperative aspects of team work on sector teams. We will deal with trust first.

2.2 TRUST

Although most controlling work consisted of an interplay between flight strip information and radar displays, vital to this was their confidence that what they saw on the screen was an accurate representation of movement in airspace.[12] Cognitively, the screen is a technological representation of a slice of sky and the relevant events occuring within it. The orderliness of the screen stands proxy for the orderliness of the sky and controllers need to be confident that this is maintained routinely. However, this trust is fragile. Distractions, or any doubt in the information to hand, undermines the controller's confidence in 'what is being seen'. 'Thinking twice' about information before them has to be avoided, and as far as RD3 was concerned, the bulk of controllers felt that, it did make them think twice. In particular, they believed that the mosaic radar data processing system (sometimes known as multihead radar

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[11] Space precludes incorporation of all the changes that RD3 involved. A synopsis of these is available from the authors on request.

[12] Strips come into their own in the case of computer failure.

assimilation) displays were not trustworthy.[13]

2.3 MOSAIC RADAR DATA PROCESSING

A number of controllers expressed the view that RD3 displays did not feel as 'firm' as ordinary displays. Close examination and comparison of RD3 with non-RD3 displays suggests some grounds for this lack of 'firmness'. 'Blips' on the non-RD3 screens are refreshed every few seconds and, due to the screen material, leave an incandescent trail. The Flight Data Blocks alongside each 'blip', derived from computer processed transponder signals, moved simultaneously with the 'blips'. Controllers, therefore, got used to the rhythm of signal refreshment. On RD3, however, 'blip's and Flight Data Blocks moved at different times mainly because the latter were not derived from transponders but from computer memory activated by the transponder signal. The general effect was to give the impression of much more movement on the RD3 screen; an impression, so to speak, that the system was 'unsure' of itself due to its unrhythmic character.

This feeling of uncertainty was reinforced by the fact that with mosaic radar data processing, controllers did not know which radar was being used. Though the system was designed to give the 'best choice', most controllers had preferences. Some did not like the clutter low coverage radars generated preferring ones with longer range; others preferred the opposite. In any event, all were familiar with the advantages and disadvantages of particular radars and thus made allowances for the faults and accuracy's known to exist with each. This knowledge was irrelevant to interpreting the signals processed by RD3 since the controller would not know which radar is being used. Further, the assimilation of information from different radars for display on a single screen could, occasionally, compound inaccuracies in the display of the aircraft's position[14]. Another problem was that RD3 signals received from beyond a selected radar's accepted limits of accuracy were displayed with extended trail markings to denote the signal's possibly inaccuracy, information which was unnecessary since such signals were only to estimate likely traffic and not for immediate controlling purposes. The extended trails were another irregularity on the screen and, since they could be large enough to obliterate other signals, were an unwanted distraction.

The fact that RD3 was not functioning on all sectors at all times impeded familiarisation with the system since even a controller willing to use it would have to use non-RD3 displays on other sectors. Since familiarity and trust are essential features of ATCO work, the tendency was to 'switch out' of RD3 to revert back to a known and trusted system. In addition, the frequent unserviceability of RD3 further inhibited opportunities for

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[13]A multihead radar display involves the selection, by computer, of the the 'most appropriate' signal relating to a particular target. Signals are received from a number of radar heads. The bulk of UK airspace is covered by more than one radar head.

[14]Every radar is inaccurate to a certain degree. If only one radar is being used then all the targets will be equally mispositioned. If more than one radar is used, then errors may add up to something quite consequential: for two aircraft seen on two seperate screens may appear to be separated but may in fact be very close. This problem actually arose when RD3 was first introduced and resulted in the temporary embargo on the system.

familiarisation and discouraged trust. But, perhaps of most importance, was the consequence of computer breakdown and the loss of all data. The age of the computer, the immense complexity of the systems driving it, the difficulties of service and maintainance, meant that breakdowns were not uncommon.[15] With the non RD3 system, on the other hand, only Flight Data Blocks were computer processed while the primary data went directly to the screens. This meant that when the computer failed, controllers still had radar data with which to work; when the RD3 system failed they had nothing but radio. (Although controllers on RD3 could switch back to old system when a failure occured, there was a lapse of approximately two minutes before the screen activated, i.e., before the transition between the two systems was completed).

Finally, apart from the lack of trust, ergonomic factors also played their part. The positioning of the message entry panel (or MEP) made easy access to telephones impossible, the panel was difficult to understand and use, input instructions were cumbersome, and so on. As one controller put it, "At busy periods you don't have time to hunt for badly placed buttons...Nice toy if you've got the time".

2.4 MEDIATOR TEAM WORK AND RD3

However, this lack of trust compounded by poor ergonomics was not the whole story. The failure of RD3 also relates to the inappropriateness of the system for the type of work engaged in on the mediator system. This was because RD3 was based on a (FAA) system designed to be used by one controller and (possibly) one assistant. According to this system, ancillary functions were either done by FDP/RDP computers, by the controller, or minimised by airspace utilisation procedures which reduced such things as coordination requirements. By contrast, the mediator system, and more generally, the airspace procedures that it was designed to service, necessitated so much coordination that one individual on the suite had to devote most of his/her time to that purpose alone. The FDP facility in the mediator system also required at least two, often four, workers per sector. Moreover, the mediator system was centred around a type of controlling so demanding as to massively restrict the controller's capacity to get involved with things like coordinations, the input of flight progress data, the preparation of strips and so on. This was because controllers were given large slices of airspace through which a multitude of airways pass. Consequently, resolution of conflictions was largely dependent upon a controller's ingenuity rather than on formal procedures. The system on which RD3 was based, in contrast, gave the controller smaller segments of airspace, with less complicated airway intersections and fewer numbers of aircraft. The upshot of all this was that the mediator system required team like working, whereas the RD3 system presupposed a more individually managed controlling enviroment.

[15]It seems that the primary difficulties were with the outdated power supply equipment and with the software. As is often the case, the original software was no longer maintained by the personnel who had designed and implemented it with the result that some of this essential knowledge was lost, to the detriment of the operational efficiency of the system. In addition, that the computer was being asked to perform more and more tasks was a further handicap. A number of computer technicians expressed the view that the software is in "desperate need of a spring clean".

The team work required in the Mediator system was based on an elaborate division of labour. Specifically, this division of labour allowed controllers to concentrate solely on controlling; that is, maintaining separations, controlling ascents and descents, etc.; whilst the coordination of traffic between and with neighboring sectors, preparing flight strips, etc. was largely done by assistants and, where circumstances demanded, by crew chiefs[16].

For example, ensuring that the right strips were placed in front of the controller at the right time was one of the basic tasks of assistants. Strips were taken from the printer, sorted into various categories and located appropriately in the bays in front of the controller. Strips would be printed for every aircraft that came through a sector and for every important navigation point it would have to cross[17]. The strips would be separated on the basis of general direction, fitting westerly in yellow, easterly in blue holders, for instance. Computer estimated time of arrivals would be corrected as necessary, and updated for other sectors. Finally, the strips would be placed in the bays in the correct sequence, usually the sooner, the lower, and in appropriate columns. Once the controller had finished using the strips, they were taken and collected by the assistants. In other words, the controller did not have to concern him/herself with the preparation of strips which was essential to the overall accomplishment of controlling but could let other members of the sector team do that work. Indeed the controller had to let these other members do this work or otherwise he/she would not be able to give all his attention to controlling decision making.

Dealing with strips was not the only function of assistants. In addition, they liaised with neighboring sectors, acting as intermediaries between controllers, and any agreement was marked down on the strips. They also drew to the attention of controllers any 'procedural conflicts'[18] by moving strips slightly out of position.

Another member of the team was the sector chief. The chief attended to unusual or difficult traffic to minimise its effect on the bulk of the traffic flow. The chief also kept an eye on all strips for any potential conflictions. At busy times, most of their time was taken coordinating with unusual traffic, such as trying to find an unused flight level, or

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[16]Sector teams consisted of assistants, who prepared the flight data strips printed by the computer and input data relevant to the strips. There were up to four assistants or 'wingmenm' on a sector dependent upon traffic load. Then the controllers themselves; again the number varied according to the busyness of the sector from one (when the sector was 'bandboxed'), to four, or even more when a 'man and boy' procedure was set up whereby a controller was watched by a non-active controller who checked on things. Then lastly, sector chiefs who supervised the running of the sector and who made strategic decisions about such things as the total volumes of traffic allowed into the sector. There is only ever one chief per sector.

[17]There were normally 3 - 4 such points each side of a sector. The FDP computer would estimate the eta for each of these points and print a strip shortly before.

[18]That is, where 2 aircraft were expected to cross a navigational marker at the same time and height.

'bridge', and liaising with neighboring sector chiefs. In addition, the chief has the ultimate responsibility for the running of the sector and the authority to instigate flow restrictions on incoming traffic, even to the extent, though rarely used except in dire emergency, of turning all traffic away.

The intersection of the division of labour around sector suites is the flight strips. By noting down on the strips any relevant details, all members of the team are able to see 'at a glance' the state of the sector, and what their responsibilities are or are likely to be. This includes the controller, who looks at the strips to see what are his/her specific tasks (Harper, Hughes, and Shapiro, 1989).

The aim of the division of labour, of the sector team, is to minimise distractions for the controller so that he/she can concentrate on expediting traffic in safe and efficient ways. Non-standard flights, particularly, were a distraction since they required more controlling attention. This is why chiefs dealt with these. Teamwork, then, enabled controllers to maximise the time they spent on dealing with the bulk of traffic and, since it maximised the traffic capable of passing through the sector, was a productive method of working even though it was expensive in terms of personnel.

Accordingly, for RD3 to be a success, it would have to offer some kind of benefits to this team working. In other words its facilities would have to resonate with the requirements of one or more of the members of the sector teams. It did not do so. It could not, for example, automatically update FDP information nor display it for all who needed it - the task of assistants. Nor could it deal, in the way that a chief could, with non-standard traffic. Of course, the facilities provided were primarily intended for the use of the contoller, but again, these were irrelvant given the work of controllers within the 'cacoon' created by the sector team. For example, though vector lines were fairly easy to access they were not used, especially at peak periods since, at such times, controlling decisions tended to relate to short distances and not the long distances that the vector line facility could help with. If anything the vector lines served only to clutter already full screens. The direct routing facility had no relevance at busy periods since there were just too many aircraft in the air to allow for direct routing. If a plane did require direct routing, say because of an emergency, fuel shortage, engine failure and so on, the chief would deal with it.

2.5 SLACK PERIODS AND USING RD3

At slack periods, however, when there was not enough work for a full team, RD3 did prove useful, particularly in respect of vector lines and direct routing. No other RD3 facilities were used to any considerable degree[19]. A survey of RD3 usage confirmed this. On the Hurn sector, for example, a

[19] Since writing the above, very recent discussions with some of LATCC's senior management have indicated that there are moves to make use of RD3's confliction warning system. Controllers are going to be required to make us of it. This was prompted by a 'near miss' in Lydd in January 1988. In current circumstances, management feel that it is ill-advised to have a confliction warning system that is not being used until operational experience has confirmed whether or not it is an "improvement which makes things worse".

relatively quite sector, RD3 was used for over 50% of the time whereas on Daventry, a notoriously busy sector, hardly at all. The direct routing gave controllers an accurate idea of where a direct routing would actually take a plane and enabled them to meet such requests from pilots more effectively. Among the few controllers who did use RD3 frequently, this was the facility most cited as helpful, although the vector line facility was said to be particularly useful in checking that aircraft on parallel headings did not drift into one another due to improperly aligned giros.

That RD3 was used only at slack times does not contradict our assertion that RD3 was largely a failure. For it serves to underline how important team work was at busy times. For then, the facilities RD3 offered were irrelevant to a controllers needs; at quite times they were useful because the controller had the time to use them and above all, was doing a slightly different task: for example offering direct routings that would hardly ever be offered at busy times. Moreover, not only did the controller have the time but controllers preferred to be doing something, even using a system that they did not really need. For keeping themselves busy kept them 'on the ball'. As one chief put it: "a busy controller is a good controller, a bored controller is one you cannot depend on."

3. CONCLUDING REMARKS

It has not been our intention to provide a complete evaluation of RD3, nor more generally, to prescribe what technological developments would be appropriate for ATC. For one thing, there has been a turning away from technologically based changes, towards changes in airspace procedures. Thus it has been proposed that the amount of airspace or sector under each controller should be far smaller and traffic should flow only one way in each sector. Instead of dividing the LTMA (London Traffic Management Area) for example in to 5 sectors, as occurs at present, all traffic within these being the responsibility of a single controller, in proposed new systems each controller will only be responsible for one-way 'corridors' of space. There may be up to 16 such 'corridors' in LTMA (this system is known as the CCF)[20].

But more importantly our concern has been to argue that the efficacy of any computer system is to be judged by how well it resonates with the social organisation of work. RD3 did not do so; indeed its facilities were inimical to expeditious controlling. In particular and firstly, it undermined trust in the technology, and second, it was irrelevant to the workings of sector teams at busy periods. Systems which are more elaborate

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[20] For example, all inbound traffic to Heathrow from the south and south eastern approaches (currently the Dover/Lyd sectors) will have to join a single route which will lead them all directly to Heathrow. This 'corridor' will have a ceiling, base and sides and will take aircraft through a large part of their descent. The corridor will be divided into sections, each under one controller who will make sure that the aircraft remain within the boundaries and at a speed which maintains adequate separation between traffic in the stream. This 'speed control' will become the basis of coordinating and sequencing aircraft into airports rather than the present hold and stack procedure. The aerodrome approach controller will be placed in the same operations room as TMA to ease coordination. It is this which gives the name to the system, the Combined Control Facility, or CCF: a system which has been in use in the New York Metroplex system for some 10 years.

than RD3 and which may, for example, be intended to support cooperative working practices, rather than just providing a data base for an individual, will also fail to the extent that they do not take account of the social organisation of the work they are intended to enhance. Consequently, insofar as system designers wish to take cooperative working practices seriously, then they will need to know a great deal more about the social organisation of work, which is, from a sociological standpoint at least, inevitably cooperative in the same fundamental sense that conversation, a row, a disagreement is cooperative. This will require giving rather less credence or weight to putative pychological factors as, for example, the Human Factors approach which has predominated in ATC tends to do, and more to the active, and actively socially organised, deployment of human expertise in the actual circumstances of work - whatever that work may be.

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