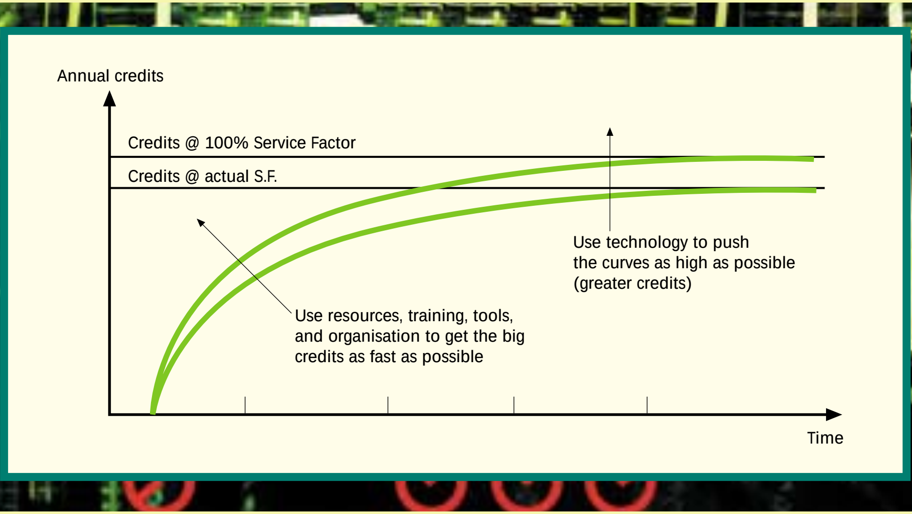

FIGURE 1: THE PICTURE SHOWS THE INCREASE IN THE ANNUAL CREDITS WITH THE INCREASING NUMBER OF APC APPLICATIONS OVER TIME. THE OBJECTIVE OF THE APC MANAGEMENT IS TO ACHIEVE THE MAXIMUM AMOUNT OF CREDITS IN THE SHORTEST POSSIBLE TIME.

ADVANCED PROCESS CONTROL OFFERS SUBSTANTIAL IMPROVEMENTS TO INDUSTRY, BUT WIDESPREAD MISUNDERSTANDINGS AND A LACK OF KNOWLEDGE HAVE HINDERED ITS IMPLEMENTATION

ADVANCED PROCESS CONTROL:

OPPORTUNITIES, BENEFITS, AND BARRIERS

by Hans H. Eder

While the name “Advanced Control” gives rise to different perceptions, most of them relate to the technological aspects of the procedure. Therefore we would like to present a more complete definition:

“Advanced Control is the intelligent, well managed use of process control technology, systems and tools, based on sound process knowledge, to enable and to benefit from operations improvements in a most cost and time effective way”.

Let us briefly expand on two of the key words:

- *Intelligent* means we are aware of the available technologies, that we have a suitable subset, a technology set, readily available on our control systems and that we know when and how to use the technologies effectively;
- *Well managed* means all APC activities are well planned, executed, and monitored, and that they are in line with plant operations objectives and based on sound standards and rules.

From this definition we can see that APC has in fact three main dimensions: technology, economics, and organisation.

EXPECTATIONS FROM APC

Process control is a service to plant operations, helping to improve the performance of the process. The goal of APC in particular is to maximise the performance and to exploit improvement opportunities (expressed in monetary terms as “credits” or “incentives”) that cannot be realised by other means. When we plot the credits achieved by APC applications over time we get a curve that very much resembles a first order process response curve – and can be described by two parameters:

a) The *gain* – that is the maximum achievable sum of credits when all possible advanced controls are implemented and running. The actual economic gain is influenced by a) the achieved performance, and this is in turn mainly dependent on the technologies used; and b) by the actual use of the control applications, their “service factor” which is very much dependent on their design, robustness and user-friendliness.

b) The *time constant* – the time needed to reach the maximum gain, which is mainly influenced by manpower, skills, planning, and the use of suitable productivity tools.

IT IS MISTAKENLY BELIEVED THAT APC IS ONLY FOR LARGE APPLICATIONS SUCH AS OIL REFINING.

WHAT IS ‘CONTROL PERFORMANCE’?

APC aims to deliver higher performance. This implies that we want to know upfront where we can and need to improve, and afterwards, what we have achieved. It also implies that we have to measure the “performance” – whatever that is. Let us look at what performance means and how we could measure it.

In the majority of cases the process must follow certain given targets as closely as possible – despite the ever present disturbances. These targets are seen as the optimal values. Every deviation to either side results in some kind of economic loss (or safety hazard). Performance is thus related to the magnitude of the variations of a certain variable or property around the target: The more we can reduce the variations, the smaller are the economic losses. We can therefore measure performance as the variance of the variable in question.

The above implies of course that the targets are set correctly and are optimal. Let us note here that the truly optimal setpoint is hardly ever identical with the setpoint calculated under the (unfortunately normal) assumption of zero variation of the process, but in fact it is also dependent on the magnitude of the variation – but this is a different subject.

FIGURE 2: SQUEEZING THE VARIANCE ALLOWS MOVING THE MEAN VALUE CLOSER TO THE CONSTRAINT.

In the case where we are pushing against a limiting value, performance is related to the average distance from the limit that can be achieved or, in case of soft constraints, to the number of violations in a given time interval. Again, these are easily measurable.

There are other situations where there is no firm target number given, where we are given only the direction to go: “Maximise the throughput” or “minimise the energy consumption” are typical objectives of this nature. In these cases we will use constraint controls that allow us to exploit even temporary chances to push further. Performance is expressed here by the average value of the variable to be maximised or minimised.

In other cases it is too difficult, if not impossible, to determine the optimum operating point off-line while simple

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model-free closed loop optimisation (also called EVOP – EVolutionary OPtimisation) can do this with very little effort. A typical example is energy-yield optimisation for distillation towers. In these cases we have to minimise or to maximise an objective function. In the case of the distillation tower the objective function would describe that we would like to make more money by squeezing out more and more of the higher value product which in turn will cost us more and more energy. We need to find thus the point where the extra income from product is in balance with the extra energy cost. The achieved value of the objective function is therefore a measurement of the performance.

> WITH APC WE CAN SQUEEZE THE VARIANCE AND SHIFT THE MEAN CLOSER TO THE LIMITING CONSTRAINT.

WHERE CAN APC HELP THE MOST?

APC does not aim to replace every simple flow controller, but should be used where the standard PID controller cannot deliver the needed performance or where operators need extra help. In general, APC works best in cases of difficult process behaviour and high performance requirements.

Some typical examples of "difficult" process behaviour are

- Long deadtime, a major difficulty for control;
- High controllability ratio CR (the ratio of deadtime to the time constant). This is a key indicator of the degree of difficulty: PID is typically well suited for CR up to 2, for values between 2 and 3, tuning becomes more difficult and time consuming and beyond 3, PID is not recommended;
- Inverse response and overshoot which leads initially to "wrong" action by any reactive controller like PID; and
- Strong interactions between variables: Dynamic decoupling can be performed with PID but it is quite difficult and thus confined to small (2 x 2) systems. Model Based Control is much easier to tune, delivers better performance, and has practically no limitation in size.

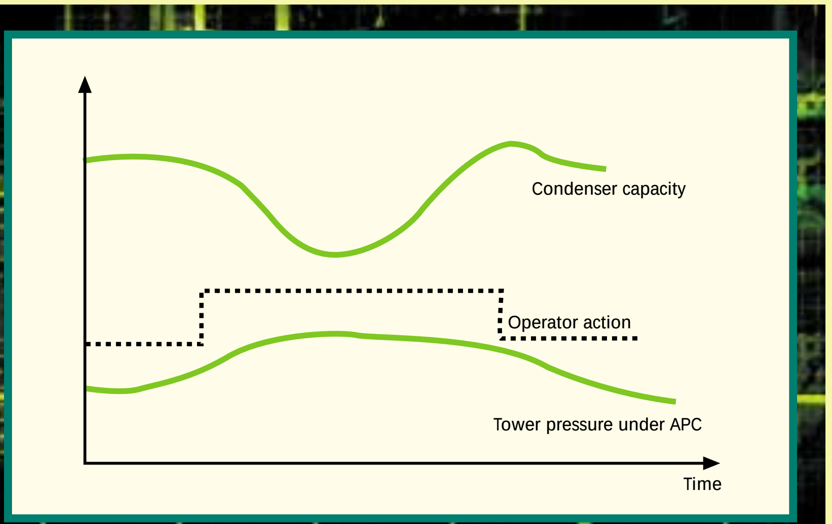

FIGURE 3: CONSTRAINT CONTROL EXAMPLE: FOR DISTILLATION TOWER PRESSURE MINIMISATION, APC ALLOWS AN AVERAGE LOWER PRESSURE.

We need to make one remark here: The common belief is that APC is mainly justified in large oil refineries because of the huge throughput of product. While this is certainly true, many successful applications have proven the value of APC in other industries. The key is, there must be enough economic leverage to justify the effort, regardless of whether that leverage comes from high product volume or from high added value.

WHAT ARE THE RESULTING BENEFITS?

We already have said that in most cases we will aim to reduce the variance of the controlled variable which will yield the following effects:

1) If the controlled variable must be pushed against a limit, then reducing the variance allows moving the average value closer to this limit. In other words: We can *squeeze* the variance and *shift* the mean! This effect is very important, since 60% to 70% of the total credits from APC come from operating closer to limiting constraints.
2) Often the controlled variable stands in a non-linear relationship with product properties. For example a temperature with zero variance would result in a certain product quality. The larger the temperature variance, the more the product quality will differ from the ideal value. The average value of the product quality is thus a function of both the average value of the temperature *and* its variance! This means that we are forced to run at a "non-ideal" temperature setpoint in order to stay on the target quality. The typical consequence is lower product yield. However, at the end of production the product is on spec, and there is no apparent problem–so the loss of yield is overlooked.

Besides the controlled variables, we also have to look at the manipulated variables, basically addressing the question: How have we achieve this performance–with minimum, reasonable, or excessive effort? This aspect should be stressed since it is easily overlooked. Good performance of the controlled variable can often be achieved with simple means, but at the price of drastic action on the process, and thus over-utilisation ("consumption") of resources. Besides, smooth action is especially important in integrated plants where any corrective action at one place means a disturbance for another variable somewhere else.

HOW CAN THE ASSOCIATED CREDITS BE DETERMINED?

The economics of the effects described above can be quantified, given that the process mechanisms are known and the economic data and some calculation tools are available. Just a few steps are required:

Step 1: Measure the current performance.

Step 2: Estimate the potential reduction of the variance. This is more difficult if no prior experience values exist. There are several methods available, but this would be the subject for another article. One easy way is to monitor the performance of the variable in question and to compare its average performance with the best demonstrated performance. This gives at least a conservative indication of the potential improvements. More realistic figures are, of course, obtained by using suitable simulation tools that allow comparison of different techniques.

Step 3: Determine the final effect(s) of the improved performance. As shown in the example above the improved performance of the temperature itself is not the ultimate goal, it is the effect on the product quality which we need to determine.

Doing this economic evaluation requires extra effort but it is clearly worthwhile. It allows us to demonstrate our achievements and may be an "eye-opener" as these data often unveil unexpected potential for savings or extra income.

WHAT STANDS IN THE WAY OF APC?

We said in the beginning that APC is far from being fully utilised – in spite of the economical attractiveness. So what are the most severe obstacles? Two stand in the way:

- Technical staff often lacks knowledge of where APC could bring extra credits and how to apply it in practice;
- Management is typically not aware of the benefits and thus is reluctant to support the required effort.

The second obstacle is only partly the fault of management, since many technical experts are unable to quantify the credits. Because of these deficiencies, we hear many defensive and often destructive arguments against APC. We will take two common objections and see if they hold at all.

> WE NEED TO LOOK AT THE COST OF NON-CONFORMANCE, NOT THE COMPLEXITY OF THE PROCESS.

"My process is too simple". The process may be simple but it still may carry a tremendous potential for improvement. By ignoring simple processes, tremendous credits can be lost. A typical example is liquid level control: A drum is a very simple piece of equipment and level control in principle also easy. Yet, a high percentage of all level controllers perform poorly, many of them causing substantial problems downstream because of the permanent swings in the manipulated flow. Using an error-squared PID instead of the standard PID is a very simple yet effective "advanced" alternative, but is hardly known and used. We need to look at the cost of non-conformance, rather than the complexity of the process.

"My process is too complex". Even for simple processes we typically see differences in the performance from operator to operator and from shift to shift. The objective should be to run the plant continuously as well as the best operator or shift. With increasing complexity the spread in the performance between different operators and shifts increases. Thus just the opposite of the statement is true–increasing complexity demands more intense use of APC.

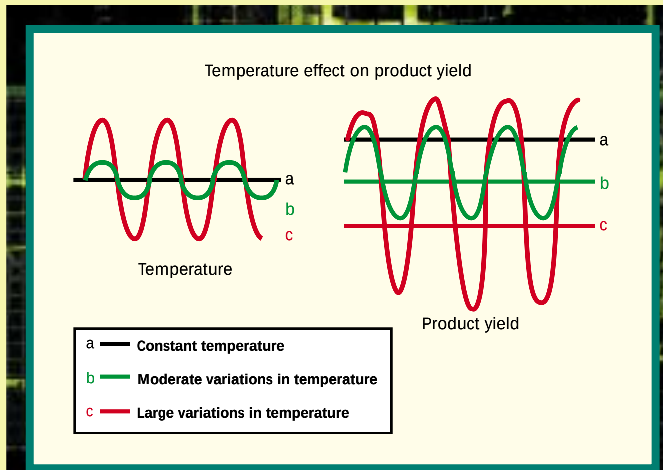

FIGURE 4: NON-LINEAR EFFECTS: THE AVERAGE TEMPERATURE IS THE SAME IN ALL THREE CASES BUT THE PRODUCT YIELD IS LOWER WHEN THE TEMPERATURE VARIATIONS ARE LARGER.

SUCCESSFUL APPLICATION DEVELOPMENT AND USE

Once we have convinced ourselves and management to apply APC then the next step is to plan for its most effective use. Before we go on let us re-state: The main objective of process control is to improve operations with controllers and applications that deliver top performance *and* are operating whenever needed. It is important to keep in mind that the latter–a high service factor–does by no means come automatically with top performance. We have to take separate, special measures.

But first, to be able to fully exploit APC capabilities several changes are required. Of all the requirements for solid performance there is one factor that stands out: *process knowledge.* The other important success factors are what we call the four T's: Technology, Training, Tools, and Tactics.

Success factor 1: Process knowledge

This is by far the most important factor. It is often stated that one of the strongest advantages of PID is that it can be used without process knowledge. In my opinion, it is one of its strongest disadvantages: during studies to locate improvement opportunities process knowledge is

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always significantly increased and has lead in many cases to changes in targets and constraints. The consequence: Quite often the development effort “pays out” *before* the first application is commissioned!

Success factor 2: Technology

Successful exploitation of advanced control demands the establishment of a Technology Set. This is the “arsenal” that allows the control engineer to find the right “weapon” for every task. It is important to have these technologies in this set which are not only best suited for the tasks but also match the company’s situation with respect to manpower, skills, and available infrastructure.

Key technical selection criteria are: Performance, ability to handle a wide range of process types, robustness, expendability, built-in constraint handling, ease of use (implementation, tuning, maintenance, and updating) and the computing requirements. Also important is the vendors’ philosophy: Some supply not only control algorithms and applications but also transfer their know-how. This puts the user in full command and enables him to maintain the application later himself. Others provide only turn-key solutions, without any know-how transfer at all, which may cause the user some dilemma at a later stage.

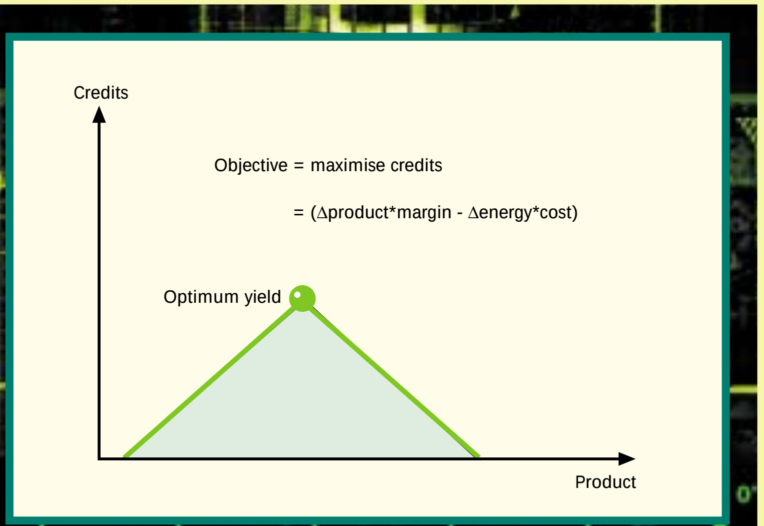

FIGURE 5: OPTIMISATION MEANS SEARCHING FOR THE POINT WHERE THE CREDITS COMING FROM EXTRA PRODUCT ARE JUST BALANCING THE EXTRA COST FOR ENERGY.

Success factor 3: Training

Since the user has to choose the technology, he must be in a position to make a good decision. He must have adequate education. Most users have some theoretical background and system specific knowledge. Yet the know-how to turn theory into working and lasting control applications is rather scarce, and so is the ability to locate improvement opportunities and to quantify the credits.

> THE TECHNOLOGY SET IS THE “ARSENAL” THAT ALLOWS THE CONTROL ENGINEER TO FIND THE RIGHT “WEAPON” FOR EVERY TASK.

Therefore *additional practice and profitability* oriented education of the control engineers comes first. After process knowledge, it is the second most important factor for success.

Success factor 4: Tools

Not only are the maximum achievable credits of concern, but also the speed by which they can be realised. This demands productivity tools for incentive calculation, performance measurement, model development, comparison of different techniques–and training and refresher courses. Again, measuring the performance plays a key role: Implementing a Performance Monitoring System is neither difficult nor work intensive yet it is a key instrument in application development and follow-up.

To stress this point I would like to use two citations, one from the U.S. and one from The Netherlands: “*What I cannot measure I cannot manage*” and “*Meten is weten, gissen is missen*” (measuring means knowing, guessing means missing).

Success factor 5: Tactics

By “tactics” we mean all the organisational means and measures needed to steer process control to maximum success. This includes standards–from tag and display naming conventions to standard control elements (*e.g.* feedforwards, analyser controls,..) – as well as guidelines for the design of human and system interfaces. Furthermore, there should be an overall “business plan” describing how and when the applications will be developed, what skills, training, human, and system resources and tools are required, and when. Only with such a sound plan we will be able to realise full economic success.

Success factor 6: Management involvement and support

Last but by no means least, this is another crucial non-technical success factor. Unfortunately, in most companies management is hardly aware of the potential contributions and benefits of process control. Often management is concerned with average, and not optimal, execution of the operating targets. The key to getting management agreement and support is to explain, *in the language of management*, the reasons for applying APC, for hiring and training engineers! This should be done in economic terms, in business language. But this, again, calls for a plan and it calls for knowledge of the economics.

PLANNING FOR SUCCESS

The steps toward a successful plan are not all that difficult: The best start is to begin by measuring the performance of key variables with a suitable Performance Measurement System. The next step is to conduct an operations improvement (“incentive”) study. The goal is to assess the current situation to locate and evaluate further improvement opportunities, besides known operational problems. Untapped, overlooked opportunities are more difficult to locate and the exploitation strategies more difficult to “sell”, therefore it is helpful to start always with the business drivers, with question like:

- What would it be worth to run 1 m^3/hr more throughput?
- What would it be worth to increase product yield by 1%?
- What would it be worth to decrease the giveaway in product quality by 1%?
- What would it be worth to reduce the consumption of energy, additives *etc.* by one unit?

Once the necessary improvements on the existing controls and the future applications, their objectives, the current and the targeted performance are defined, then just as for any project, we have to determine the potential incentives. Once they are known we can easily calculate how much we are allowed to spend using standard techniques like Discounted Cash Flows (DCF) and Internal Rates of Return (IRR). When the economics speak for the project then we can go ahead, select the technology, put this into our overall process control business plan, and start developing the applications one after the other according to this plan.

TAKE THE FIRST STEP

APC technology is mature and the computing platforms are available. Today there are no serious technical hurdles that prevent us from harvesting the benefits. Once the incentives are determined, the remaining barriers typically break down. To achieve the maximum benefits, however, we must plan carefully and observe the key success factors, just as for any other project. It certainly means extra effort, but the rewards have proven worth it, in many different industries, on many different processes, in many different locations.

A key action in any case is to undertake the first step. Start measuring the dynamic performance and take a serious, unbiased look at the improvement potential in the plant. To benefit the most on a long term basis, all future conventional and advanced controls should be defined before a new DCS system is purchased. This will assure that the best platform is available so that applications development can go on without running into capacity or functional limitations. Where a suitable DCS is already in place, APC has proven to be the most cost and time effective way to improve plant operations and profitability. ■

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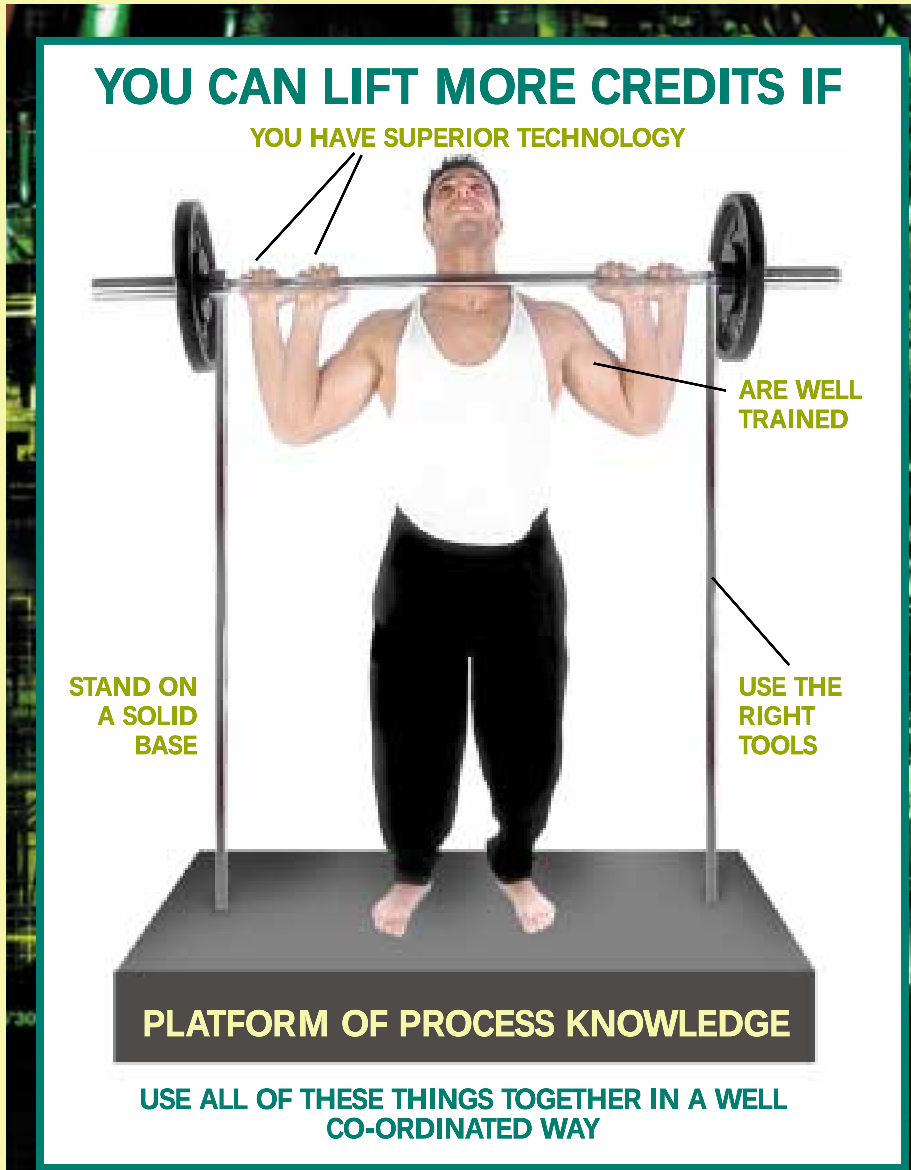

FIGURE 6: YOU CAN LIFT MORE CREDITS IF YOU HAVE SUPERIOR TECHNOLOGY, ARE WELL TRAINED, USE THE RIGHT TOOLS, STAND ON A SOLID BASIS, AND USE ALL OF THESE THINGS TOGETHER IN A WELL CO-ORDINATED WAY.