This is an unpublished, unchecked and preliminary piece written by Gerry Martin in April 1998, upon which discussion was based. Please treat accordingly.

INTRODUCTION: PRELIMINARY REFLECTIONS ON SOME PROBLEMS AND APPROACHES

The puzzle; an archeological fantasy

Imagine that in five hundred years' time a large meteorite hits the earth and that a huge cloud of dust is thrown up into the atmosphere, which settles over the land covering nearly everything to a depth of a couple of metres - a sort of catastrophic Pompeii. Everyone is killed except for a few million people on the shadow side of mountains.

Gradually these people re-establish organized life, so that in three thousand years' time a thriving civilization is again populating the world. They know that everywhere beneath them is evidence of their ancestors and they develop a great interest in archaeology, and great expertise in the precise dating of the artifacts they dig up.

Teams go out to all parts of the world and dig down through thousands of years of history. A hundred teams dig sites in Japan, a thousand in China, a thousand in India and in Russia, in Africa and the Americas. Many hundreds of sites are dug around Europe.

The archaeologists bring all their finds back to one central field for study and, just as many archaeologists do today, they lay the artifacts out on long rows of wooden tables so that all the artifacts from any one site were laid out in a row, but in strict chronological order.

Imagine that we spend a few days walking up and down the tables, trying to understand what we see. Suppose we put marks on the tables at one thousand year intervals, and then we look at the changes in the artifacts between the beginning and the end of these thousand year periods.

Ten thousand years ago it would be very difficult to see any difference at all between artifacts a thousand years apart, although from a very few sites we would start to see faint evidence of one of the most important changes in human history, the change from hunter-gatherer to farmer.

Once clusters of farming communities became established the pace of change accelerated, for instance along the Fertile Crescent of Mesopotamia, along the Nile Valley of Egypt, in parts of Pakistan and of China, and bursts of rapid change would appear in the archaeological record.

Most of these changes were decorative, for instance the decoration on pottery or in clothing and jewellry, but some were functional and these were and are the type of change which makes an appreciable difference to the way people live.

By the first century B.C. we would see a large range of artifacts in use, and mastery of a wide range of materials. Copper and bronze, gold, silver and iron, glass and resins and a variety of natural fibres and of ceramics. Ploughs, boats that could sail far from land, wheels for carriages and pipes for water. We would see quite clearly that some sites had a wide range of artifacts in use, and a rapid rate of innovation of artifacts, while other sites - the majority - had hardly any innovation.

In the thousand year period before 1200 A.D. other important changes would become apparent. China would show itself to be the most advanced civilization, with extensive manufacture of high quality products, efficient agriculture founded on large scale hydraulic engineering, effective and reliable sea travel.

The Arab civilization would be at its peak, with mastery of agriculture, many fine buildings, great control over the supply of water, precision working of metals and of glass, and above all a reverence for knowledge - knowledge systematically brought in from the Greeks, from Byzantium and from the East, as far away as India and China.

By 1200 A.D. another important aspect of change would be clear from the archaeological record - that stasis or even decline were just as much part of human experience as was 'progress'. A few centuries of development, represented on our wooden tables by rapid change in functional artifacts, is always followed by either a dropping back to some simpler state, with the loss of many skills, or by a plateau in which most of the old skills were preserved, but with the rate of innovation dropping to a very low level.

There were no exceptions to this. By 1500 A.D. China and Islam had substantially stopped innovating; the Roman, Hellenic, Egyptian and Mesopotamian innovative periods had left a great legacy to be picked up and built upon in future clusters of innovation, but none of our archaeological sites would show continuous innovation. All would show, ultimately, decline or at best a high equilibrium - and this means that these sites would quite soon become backwards, compared with innovating parts of the world.

Yet the sites from Europe would show an interesting departure. Around 1000 A.D. Europe would be seen as a backward, peripheral area of the world. Chinese and Islamic technology and civilization were far ahead. By 1900 A.D. the situation had changed completely. A very substantial range of quite new artifacts had come into existence, showing a rate of innovation on many of our sites far exceeding that seen before on any of the non-European sites.

Certainly there was some clustering, some localizing of innovation at different periods, such as a clustering around Northern Italy between 1200 A.D. and 1500 A.D., around Southern Germany somewhat later, in the Low Countries in the 16th and 17th centuries and in the British Isles in the 17th, 18th and 19th centuries. Yet the innovations in any one part of Europe drifted, sometimes quite rapidly, around Europe as a whole and were taken up wherever the local cultural and economic climate were congenial.

In this movement of the centres of innovation we see the old phenomenon of rise and decline, but we see it in an interesting setting, in which the rise in one area, as a consequence of innovation, spills over into another area and is continued and taken forward so that when the first area declines, as it always does, it has a neighbour who is moving ahead in innovation and whose products spill out, not merely to the declining region, but are available to all the regions around.

As we walk up and down our European tables, we will soon observe another interesting phenomenon - that the lines of artifacts are starting to incorporate new knowledge, knowledge that has simply not been available to previous periods. Nowadays we call this scientific knowledge, but this can be a rather misleading term, and it is more helpful, following John Ziman, to call this 'reliable knowledge', that is knowledge that has been tested, usually by experiment, in a variety of circumstances and shown to have high reliability and universal applicability so that the knowledge will be reliable and testable anywhere in the world.

Reliable knowledge, scientific knowledge, is of limited use to humanity until it is embodied in artifacts - products - but then it can have an enormous impact. Reliable knowledge has been around for millennia - for instance, when a drug company discovers a new drug which cures a widespread serious disease we call is 'science'. When, many centuries ago South American Indians discovered a drug - quinine - that is still the ultimate drug of choice against malaria we tend not to call it science, but it is reliable knowledge.

It was in Europe that this process of generation of new reliable knowledge became established on a steadily growing basis. There had been plenty of instances of new reliable knowledge before, sometimes remarkably sophisticated - subtle and ingenious processes for the refining of zinc in India, systematic astronomical measurements, using carefully contrived instruments, in China and in Islam, even an astronomical predictor incorporating 32 gears, dating from 80 B.C. and originating in the Aegean Islands. But these clusters of intellectual activity were sporadic and the innovation eventually died away, even though the intellectual and material processes they gave rise to may have continued for a long period - an intellectual version of the high level equilibrium.

This process of the generation of new reliable knowledge and its embodiment in new functional artifacts, represents, after the hunter-gatherer/farmer transition, the second great change in human experience.

This, then, is a view of Europe's economic growth over a thousand or so years. Two component growths - new knowledge and new functional products plus, of course, a large but diminishing measure of wealth acquisition by the old zero-sum business of invasion and colonization.

A way of approaching the problem; the relations of knowledge and action

Given these puzzles of differential growth, our problem is to understand the mechanism of major shifts in human activity, for instance from hunter-gatherer to farmer, from small scale craft based artifact production to sustained industrialization, from craft skill to sustained technological innovation, from knowledge based on experience of particular cases to reliable, tested and more universal knowledge, and from techniques for acquiring and transmitting craft tacit knowledge to techniques for acquiring and transmitting new reliable knowledge.

At the heart of the problem lies the relationship between knowledge and practice or activity, and in order to think more clearly about this we need to pursue definitions and links.

The concept of 'reliable knowledge' has proved useful in thinking about science and about relationships such as the relationships between atoms and atoms, and atoms and energy; not as absolutely reliable knowledge, which is way beyond human experience, but as knowledge which is testable, potentially refutable, universally applicable within carefully defined boundaries. Reliable knowledge is knowledge which provides a 'fit' through experiment or by careful observation with our experience of nature.

It is possible that the following syndrome is a way of thinking about the problem. There is the generation of new knowledge ; this may lead to the innovation of new artifacts ; this may develop into the quantification or mass production of new artifacts ; which in turn makes possible the generation of further new knowledge.

But what are the characteristics of the first and crucial feature, namely 'reliable knowledge'? Here is a brief list of some of the possible attributes or features.

1) **The enduring nature of knowledge**.

Knowledge, both reliable knowledge in the modern, scientific sense but also knowledge in the sense of proven technological knowledge seems to endure well over very long periods, with the proviso that the knowledge is recorded and the records are widely disseminated. This cannot be a **law** - if reliable knowledge was generated, say, in Baghdad in the 12th century, ten manuscript copies produced and distributed throughout Islam, and all quickly lost to fire, the knowledge would not endure. But in practice, much knowledge, probably most knowledge, does endure. Of course, knowledge endures more completely since the advent of printing, and particularly movable-type printing, because more copies are produced, and mechanisms for distributing them and storing them for easy access are developed.

The enduring nature is comparative - but compares very favourable with conditions such as liberty, or the nation state, or democracy, or language, or the ability or desire to manufacture artifacts.

In accounting terms, the stock of knowledge hardly depreciates. (This point is capable of considerable expansion, showing how knowledge is capable of being made increasingly reliable, and how, through examination of extant old artifacts, the knowledge embodied in the artifact has or has not endured).

2) **Knowledge is cumulative**

If it is agreed that knowledge has a strong tendency to endure, and new knowledge is generated at a greater rate than existing knowledge is lost, then it follows that knowledge is cumulative.

It is difficult to think of any other human attribute which is cumulative in this sense, with the possible exception of mutations in the genome.

3) **Knowledge is an absolute requirement for the innovation of artifacts.**

In the long post-hunter-gatherer period, the overwhelming majority of resources used by humans (including agricultural products) are artifacts, and thus require knowledge.

4) **The non-linear relationship between knowledge and artifact innovation**

The possibility of innovation of artifacts increases much more rapidly than the amount of knowledge or data available. It seems probable that innovative or creative possibility increases with available knowledge at a rate steeper than a square law. In fact, it can be demonstrated in a fairly rigorous way that the ratio is **much** steeper. The consequent proliferation of artifacts is arguably the central feature of western civilization.

5) **Artifacts cannot be made unless they are makeable**

This may seem an absurd and self evident statement, especially in a list of the attributes of reliable knowledge; it is, in fact crucial to an understanding of the scientific revolution.

We gain knowledge of the natural world by observation or by experiment. The growth of experiment, specifically for the purpose of generating new reliable knowledge is the prime characteristic of the period of rapid increase in the rate of generation of knowledge which we term the scientific revolution.

Experiments construct apparatus - artifacts - in attempts to isolate phenomena they want to examine, and to generate around this phenomena a number of variables. They observe the effects and try to draw firm, repeatable, and hence 'reliable' conclusions about these relationships.

If the apparatus cannot be constructed, then that particular experiment cannot be performed. This will be demonstrated with a few examples below.

6) **The non-lineal relationship between the generation of new knowledge and the innovation of artifacts**

This is the converse of 4). The generation of new knowledge by experiment rests on the ability to make the artifacts required for the experiment (5, above).

The **possibility** of generating new knowledge experimentally will grow non-linearly from the base of old knowledge because of the **possibility** of the non-linear growth of innovative artifacts for experimental purposes.

The six attributes listed above are all attributes of knowledge. 2, 3, 4 and 6 could possibly, I think, be classified as reliable knowledge and used with confidence in historical analysis. Numbers 1 and 5 are matters of degree - pretty reliable, but their limitations in particular cases are to be remembered. Still, I think, suitable for cautious use as 'reliable'.

7. **The tendency to equilibrium of knowledge and artifacts.**

The seventh attribute does not concern knowledge as much as artifact-as-resource.

All locations/societies which have, for whatever reasons, become sites for high rates of artifact innovation and artifact production have within a few generations become sites of much lower artifact innovation and artifact production.

We include this attribute of reliable knowledge simply because it has always happened. The historical record is full of instances of innovation/production clustering in societies, but there are no cases of high innovation/production being maintained in one location for long periods - more than two or three centuries.

Of course, the world taken as a whole, as viewed by a Jovian anthropologist, would defy the rule. Europe taken as a whole would defy the rule over the last thousand years. The United States viewed over the short time span of the past three hundred years may appear to defy the rule. But as we examine locations on a finer scale the rule seems to be universal.

The knowledge-artifact-knowledge loop further defined.

The purpose of this work is to illuminate the factors important in the generation of new knowledge, both reliable knowledge and tacit or craft knowledge, and the embodiment of knowledge in order to innovate new artifacts.

We want to develop a better tool for understanding change and stasis in societies. One way to approach this is through the following syndrome, whereby for certain periods there is a movement through the following sequence:

a. the generation of new reliable knowledge
b. innovation of new artifacts

c. quantification or widespread diffusion of new artifacts
e. generation of new tacit and reliable knowledge

It seems likely that this syndrome is one of the primary motors of change in societies, and that its frustration is one major cause of 'traps' which are occurring constantly in all societies.

We therefore need to examine each component of the syndrome in order better to understand the conditions favourable to the development of each component and the conditions likely to frustrate them, as well as the conditions which bear on the smooth working of the loop or syndrome as a whole.

We also need to check back frequently to see if the syndrome continues to be a useful measure of change and its absence or partial absence a relevant measure of stasis or decline.

In order to do this we need to develop better understanding of the terms 'science' or 'scientific knowledge', tacit knowledge, craft knowledge and craft skill, technology, manufacture, artifact, innovation and resource.

We need to analyse and describe each of these in such a way that we can use each term as a consistent means of communication, and in a manner most useful to understanding the part played by each part of the syndrome on the working of the syndrome as a whole.

Most of the understanding of the conditions conducive to the growth, or frustration, of each of these components will be drawn from the literature, but we hope to make some contribution to current understanding of the reasons for the growth of reliable knowledge and the rate of artifact innovation by examination of the relationship between separate societies, their 'boundedness' and their 'leakiness'.

We also hope to be able to develop some useful generalizations about 'traps', stasis, 'decline', and to test these generalizations against a variety of historical situations.