Introduction intention of modelling a simple version

INTRODUCTIONWhile most branches of physics studypredictable notions such as electricity or classical mechanics, chaos theoryrefers to that which is nonlinear and unpredictable.

That which is encompassedin chaos theory can be considered to be out of our control, such as theweather, which was in fact how the discovery that led to chaos theory occurred1. Chaos theory refers to thebehaviour of systems that are highly sensitiveto their initial conditions. It was born from a phenomenon discovered byEdward Lorenz in 1972 called the ' butterfly effect'. This refers to an ideathat most systems that change over time, be that natural or artificial, willdiffer if just the tiniest adjustment is made to their starting point. A wellnoted quote illustrating this was given by Philip Merilees who said, " Does theflap of a butterfly's wings in Brazil set off a tornado in Texas?" 1 Thisquestion sparked the beginning of a whole new field of research called chaostheory.

DISCOVERY OF CHAOS THEORYLorenz was working as aresearcher for the Massachusetts Institute of Technology when he combined meteorologywith mathematics and computing. He built a processor with the intention of modellinga simple version of the weather. His breakthrough regarding the butterflyeffect happened as he put numbers into his computer to rerun a simulation. The resulthe got was drastically different from what he expected to see and when looking intoany possible errors, he realised that all he had done was rounded one of thevalues, using 0. 506 instead of 0. 506127. 1 It was here that Lorenzrealised that small changes can have largeconsequences, and this is what eventually came to be known as thebutterfly effect. This accidental discovery had a paramount corollary which was that forecasting the future canbe nearly impossible.

Lorenz’s work was so ground-breakingas it challenged the classical understanding of nature published in 1687 byIsaac Newton. He had suggested a predictable system known as the “ clockworkuniverse” 9, but Lorenz’s discovery contradicted this. Not onlydid he spark a new theory of the way the universe works, his discovery also became the foundingprinciple of chaos theory, which expanded rapidly and vastly during the 1970sand 1980s.

It eventually came to be extremely important in fields of sciencesuch as geology, biology and meteorology. “ It became a wonderful instance of aseemingly esoteric piece of mathematics that had experimentally verifiableapplications in the real world,” says Daniel Rothman, a professor of geophysicsat MIT. 9EXAMPLES AND EFFECTS OF CHAOSTHEORYFrom this we noticed thatchaos can be found everywhere you look. One example of this is our solarsystem, this qualifies as a chaotic system because it involves the interactionof more than two bodies. Considering that it contains 8 planets (9 if you likePluto), the sun, 181 moons 4 and countless asteroids and comets, our solar system is rather chaotic. But if our solar system is as chaotic as itseems to be, how can we possibly hope to predict its fate? The answer is thatwe simply can’t. It is impossible to predict thefate of our world because the smallest error could cause a drastic change inthe outcome.

5 However this does not mean that our solar system isfated for a violent demise, in fact these chaotic orbits tend to be ‘ bounded’which means that

they move in cycles that never repeat identically, but arecontained within a limited volume of space. This limits the danger of collision. 1 Another example of a chaotic system is adouble pendulum, where two rods are joined insecurely and allowed to swingfreely. The unpredictability exhibited by this system illustrates the random motionthat we expect to see in a chaotic system. The bottom pendulum traces a patterncontaining loops. This pattern illustrates an attraction to a certain form.

Thisis where the ‘ strange attractor’ came from. The most well-known example of astrange attractor is the Lorenz attractor (shown in figure 1), this is a map ofthe movement of a chaotic system in three dimensions 1. It illustratesthe random motion of a chaotic system as it shows that two points on the attractor that arenear each other at one time will be arbitrarily far apart later on. 7 The fact that these systems are boundeddoes not mean that they can’t have extreme consequences. This is exhibited bythe effect that the planets in our solar system can have on each other. Althoughthe orbits do not deviate significantly, the chaotic motion has the possibilityof causing a catastrophic danger.

For example, a tiny knock to Saturn from theparticles in the solar wind could make its orbit aperiodic. 1 Thismeans that its path will change each time it orbits the sun. This opens up thepossibility that Jupiter, Saturn and the Sun will align at some point. The combinedgravitational pull of this trio would be enough to pull rocks out of theasteroid belt that lies between the orbits of Jupiter and Mars, causing anasteroid storm.

Some scientists believe that such an event preceded theasteroid impact that ended the age of the dinosaurs, this shows the drasticeffect that chaos could have on the Earth. However, the possible effects of chaostheory aren't all bad. In fact, chaos theory has brought about a greaterunderstanding of certain illnesses and has therefore caused medical advances. Theup and down pattern of epidemics such as AIDS, measles and polio follows achaotic trajectory, meaning that it is sensitive to the tiniest variations; forexample, an inoculation programme. 1 Theorists call it ' bifurcation'which refers to the qualitativechange in the dynamics of a system produced by varying parameters.

8 Theintroduction of an inoculation programme can cause the epidemic to be throwninto a chaotic frenzy. This means that the short-term figures for the diseasemay increase, however awareness of chaos allows medical researchersto ignore the short-term issue and allow for a chaotic response. This response suggeststhat it should be followed by a downward trajectory in the long term. 1FRACTAL PATTERNSThese phenomena are often described by fractal mathematics, which capturesthe infinite complexity of nature. Many natural objects exhibit fractalproperties, including landscapes, clouds, trees, organs, rivers etc, and manyof the systems in which we live exhibit complex, chaotic behaviour. Recognizingthe chaotic, fractal nature of our world can give us new insight, power, andwisdom.

For example, by understanding the complex, chaotic dynamics of theatmosphere, a balloon pilot can " steer" a balloon to a desired location. Byunderstanding that our ecosystems, our social systems, and our economic systemsare interconnected, we can hope to avoid actions which may end up beingdetrimental to our long-term well-being.